

CANMET

L'énergie et l'environnement •
energy and the environment •

**Les 20 et 21 mars 1991
Centre Sheraton • MONTRÉAL (Québec)**

**March 20 & 21, 1991
Sheraton Centre • Montréal, Quebec**

ENERGY AND THE ENVIRONMENT

CONFERENCE AGENDA

307 pp



Énergie, Mines et
Ressources Canada

Energy, Mines and
Resources Canada

Canada

L'ÉNERGIE DE NOS RESSOURCES - NOTRE FORCE CRÉATRICE

THE ENERGY OF OUR RESOURCES - THE POWER OF OUR IDEAS

CONFERENCE AGENDA
ENERGY AND THE ENVIRONMENT
MARCH 20,21 1991

DAY 1: March 20, 1991

- 8:00 **Registration**
- 8:50 **Coordinator for the morning session**
 Stelios Pnevmticos
 Director, Energy Diversification Research Laboratory
 (EDRL) CANMET
- 9:00 * **CANMET's Programs on Environmental Research and Development**
 Marc-Denis Everell
 Assistant Deputy Minister, CANMET
- 9:20 * **Environmental Stakes and their Effects on the Energy Sector**
 Alain Ste-Marie
 President, Association québécoise pour la
 maîtrise de l'énergie, (AQME)
- 9:50 **Coffee Break**
- 10:20 * **Perspectives on Energy and Environment**
 Claude Brouillard
 President,
 Canadian Petroleum Products Institute
- 10:50 * **Position of the Canadian Industry regarding Electricity and Environment**
 Maurice Huppé
 President, Canadian Electrical Association
- 11:20 **Impact of Natural Gas on the Environment**
 John Klenavic
 Vice-President, Government Relations
 Canadian Gas Association
- 11:50 **Lunch**

- * **The presentation will be in French. Simultaneous translation will be available on request.**

DAY 1 (cont'd)

TECHNICAL SESSION**Energy Efficiency**

- 1:25 **Coordinator for the Afternoon Session**
Gilles Jean
Assistant Director
EDRL, CANMET
- 1:35 * **Indoor Air Quality : A Poorly Documented Problem**
Hani Bazerghi
Chalifour, Marcotte et Associés (CMA)
- 1:55 * **Efficient Combustion Technologies for Heating -
Reducing Energy Use and Pollutant Emissions**
Skip Hayden
Head, Energy Conservation Technology Section
Energy Research Laboratories (ERL), CANMET
- 2:15 **Demand-Side Management and the Environment**
Michael Conroy
District Manager
Central Main Power
- 2:35 * **Demonstration of Energy Efficiency in Industrial
Processes**
Louis Monier
Director, Laboratoire des technologies
électrochimiques et électrotechnologies
d'Hydro-Québec (LTEE)
- 3:05 **Coffee Break**
- 3:35 **Technical and Economic Advantages of District
Heating/Cooling Coupled to Electricity Generation**
Michael Wiggin
Program Manager, Energy Systems Technology
Implementation
ERL, CANMET
- 4:05 **Pinch Technology: the Integrated Approach to
Industrial Processes**
Jigar V. Shah
Business Development Manager
Linnhoff March

- * **The presentation will be in French. Simultaneous
translation will be available on request.**

DAY 1 (cont'd)

4:35 **Gas Heat Pumps**
 Martin McCall
 Manager, Residential and Commercial Technology
 Consumer Gas

5:15 **Reception**

DAY 2: March 21, 1991

TECHNICAL SESSION A

Alternative Energies

- 8:30 **Coordinator for the Morning Session**
Allan Dolenko
Director
Alternative Energy Division, CANMET
- 8:40 **Critical Assessment Review of Photovoltaic**
Don Adkinson
President, Canadian Photovoltaic Industry Association
(CPIA)
- 9:00 **Potential Market for Fuel Cells Technology in Canada**
Keith Prater
Vice-President, Ballard Power Systems Inc.
- 9:30 * **Solar Developments for Buildings**
Richard Côté
President, Association Québec Solaire
- 10:00 **Coffee Break**
- 10:30 * **The Impact of Renewable Energy on the Environment in
Canada (Potential and Challenges)**
Christian Ouellet
Vice-president, Solar Energy Society of Canada Inc.
(SESCI)
- 11:00 * **Cogeneration: Gas Turbines Application in Industry**
Pierre Gauthier
Manager, Groupe Datech
Gaz Métropolitain
- 11:30 **Environment Quality and Renewable Energy**
Jay Barclay
Deputy Director, Office of Environmental Affairs
Energy, Mines and Resources Canada

- * **The presentation will be in French. Simultaneous
translation will be available on request.**

DAY 2 (cont'd)

TECHNICAL SESSION B

Waste Energy Management

- 8:30 **Coordinator for the Morning Session**
Joe Robert
Chief, Bioenergy Group
Alternative Energy Division, CANMET
- 8:40 * **The State of R&D in Waste Energy Management**
Jean-Maurice Charron
Technology Officer, Biomass Combustion
Alternative Energy Division, CANMET
- 9:00 * **The role of Energy Valorization in a Plan for
Integrated Waste Management**
Guy Racine, Director General
Régie intermunicipale de gestion des déchets sur l'île
de Montréal
- 9:30 **Status Report on Environment Canada's Oil from Sludge
Technology**
Herbert Campbell
Chief, Residue Management Division
Waste Water Technology Center
Environment Canada
- 10:00 **Coffee Break**
- 10:30 * **Research in the Field of Forestry Biomass in Quebec**
Marcel Risi
President, Director General
Centre québécois de la valorisation de la biomasse
(CQVB)
- 11:00 * **Utilizing By-product Waste as Electric Furnace
Feedstock**
Jacques Bureau
Senior Advisor
Albright & Wilson
- 11:30 **Oil Sands Sludge**
Hassan Hamza
Coal Research Laboratory, CANMET
- 12:00 **Lunch**

* **The presentation will be in French. Simultaneous
translation will be available on request.**

DAY 2 (cont'd)

TECHNICAL SESSION C

Transport

- 1:30 **President for the Afternoon Session**
Jean Denis
Manager, Synthetic Fuels Research
Energy Research Laboratory (ERL), CANMET
- 1:40 * **Environmental Policies and Future Regulations on Fuels**
Frank Vena
Chief, Transportation Systems Division
Environment Canada
- 2:00 **Canada's Position Regarding Alternative Fuels**
Tony Taylor
Director
Transportation Fuels
Efficiency and Alternative Energy Branch
Energy, Mines and Resources Canada
- 2:30 * **Liquid Fuels made from Natural Gas**
Vincenza Allenger
Head, Hydrocarbon Conversion Section
ERL, CANMET
- 3:00 **Coffee Break**
- 3:30 **Forum**

Energy Technologies as Environmental Solutions
Special speaker: Jean-Marc Carpentier

* **The presentation will be in French. Simultaneous translation will be available on request.**

PARTICIPANTS
"ENERGY AND THE ENVIRONMENT" CONFERENCE

Pierre Markon	-	Bureau Efficacité Energétique
Robert Hensley	-	Bureau Efficacité Energétique
Luc Gagnon	-	Ministère Environnement
Douglas Labelle	-	Bureau Efficacité Energétique
Richard Montreuil	-	C.H.U.L. Que.
Patricia Kaufman	-	Min. Aff. Internationales
Linda Lord	-	Min. Aff. Internationales
Mario Tardif	-	Société Immobilière du Québec
Wally Geekie	-	EMR Canada
Michel Bérubé	-	EMR Canada
Philippe Desjardins	-	Ener.Ress. Quebec
Francoise Mougeat	-	Ener.Ress. Quebec
Michel Fortier	-	Société Immobilière du Québec
Jean-Guy Gélinas	-	Société Immobilière du Québec
Yves Lacharité	-	Société Immobilière du Québec
Mark Pierson	-	EMR
Richard Fry	-	Ministère Energie de l'Ontario
Luc de Passillié	-	Ener. et Ress. Que
Georges B.B. Lè	-	Ener. et Ress. Que
François X. Simard	-	Environnement Canada
Bruno Paradis	-	Bioshell Inc.
Réjean Lemieux	-	Hôpital Laval
Richard J. Béraud	-	Gaz Métropolitain Inc.
José-Luis Munoz	-	Gaz Métropolitain Inc.
Paul-Henri Croteau	-	Hydro-Québec
Guy Bédard	-	Commission scolaire d'Alma
Jocelyn Harvey	-	Commission scolaire d'Alma
Patrick Brouillette	-	Les chaudières Foster Wheller Inc.
Roger Chen	-	Ontario Hydro
S. Szilard	-	Consumers' Gas Co.
Fernand Lamarre	-	Hôpital Général de Montréal
Cécile Granger	-	Assoc. canadienne de l'électricité
Jacques Fréchette	-	Hydro-Québec
Jocelyne Pellerin	-	Hydro-Quebec
Robert Boutollo	-	Royal Bank of Canada
J.G. Brouillette	-	Hewitt Equipement Ltée
Meli Stylianou	-	Siricon
Jacques Murray	-	Produits chimiques Magnus
Dominique Ferrand	-	Groupe NRJ
Jean Bergeron	-	SKW Canada
Gérald Cotton	-	Sucre Lantic Ltée
JFrancois Pinsonneault	-	SANITECH-LAVALIN
Jean-Marc Lambert	-	ABC Energie & chaudières
Jean-Pierre Riberdy	-	Sucre Lantic Ltée
Thuan Nguyen-Dinh	-	Sucre Lantic Ltée
Denis Leclerc	-	Swift Textiles
Pierre-Marie Dubois	-	Société de Transports de Laval
R. Cleary	-	Pratt & Whitney
David Cheeke	-	Siricon

Stanislas Kajl	-	
Jean-Marie Sala	-	Alcan Ltée
Nick Standon	-	Pratt & Whitney
S. Bisson	-	CIMA-LNR et Associés
S. Chenail	-	CIMA-LNR et Associés
Maurice Robert	-	Consultants VFP Inc
Réjean Carrière	-	Kruger Inc.
Richard Châtigny	-	Innovation techno. Intek Inc.
Frank A. Hlohovsky	-	Memac
Jean Gagnon	-	Agropur
Vincent Roquet	-	Option Amenagement Inc.
Michel Noirfalise	-	Dow Chemical
Michel Primeau	-	Alcan Ltée
G. Bernardin	-	Ciment St-Laurent Inc.
Laurie Gauvin	-	Consultants CGTS Inc.
Léo Pancourt	-	SNC Inc.
J.E. Klimpt	-	
Guy Painchaud	-	C.R.I.Q.
Paulo Koeberle	-	Université de Sherbrooke
Samuel Sami	-	Université de Moncton
Pierre Roy	-	C.R.I.Q.
Charles Leigh	-	IREQ
Eric Usher	-	Queen's University
Ben Abdalha	-	Technical Univer.of Nova Scotia
Nick D. Markettos	-	C.F.F.T.P. (Ontario Hydro)
Michel Boulanger	-	C.R.I.Q.
Michel Parent	-	C.R.I.Q.
W.K. Azarniouch	-	Pulp & Paper Research Inst. Canada
Benoit Jean	-	INRS Energie
Pierre Laborde	-	Centre de valorisation de biomasse
Fernand Rhéault	-	INRS Energie

GUESTS

Claude Barreau	METS	Jean-Pierre Desrosiers	DEEER
Jocelyn Plourde	DEEER	Jean-Louis Bibeau	CEMR
Luc Lalande	EMR	Leslie Dawes	EMR
Cliff Adams	LRE	Patrick Van Gheluwe	LRDE
Bernard Cantin	GREENPEACE	René Miglierena	APCEC
Gilles Bouthillier	ALBRIGHT & WILSON	Michel Poirier	LRDE
Jean Burcombe	AU COURANT	Benoit Bergevin	LRDE
Pierre Thisdale	JOURNALISTE	Jimmy Royer	LRDE
Lise Tremblay	ALBRIGHT & WILSON	Sylvain Martel	LRDE
Frank Crocker	ALBRIGHT & WILSON	André Champagne	LRDE
Brendan Hawley	APCEC	Mark Riley	METS

GUESTS SPEAKERS
"ENERGY AND THE ENVIRONMENT CONFERENCE"

MARC-DENIS EVERELL
SOUS-MINISTRE ADJOINT
ENERGIE, MINES ET RESSOURCES CANADA
CANMET
TEL: 613-992-9983
FAX: 613-992-8874

ALAIN STE-MARIE
PRESIDENT
ASSOCIATION QUEBECOISE POUR
LA MAITRISE DE L'ENERGIE
TEL: 514-284-2596
FAX: 514-598-3461

CLAUDE BROUILLARD
PRESIDENT
ASSOCIATION PETROLIERE POUR LA CONSERVATION
DE L'ENVIRONNEMENT CANADIEN
TEL: 613-232-3709
FAX: 613-236-4280

MAURICE HUPPE
PRESIDENT
ASSOCIATION CANADIENNE DE L'ELECTRICITE
TEL: 514-289-3810
FAX: 514-937-6498

JOHN S. KLENAVIC
VICE-PRESIDENT, GOVERNMENT RELATIONS
CANADIAN GAS ASSOCIATION
TEL: 613-234-6140
FAX: 613-232-4806

HANI BAZERGI
CMA CHALIFOUR, MARCOTTE ET ASSOCIES INC.
TEL: 514-694-4141
FAX: 514-694-1713

SKIP HAYDEN
HEAD
ENERGY CONSERVATION TECHNOLOGY SECTION
ENERGY RESEARCH LABORATORIES (ERL)
TEL: 613-996-3186
FAX: 613-995-9584

MICHAEL CONROY
DISTRICT MANAGER
CENTRAL MAINE POWER
TEL: 207-564-7155
FAX: 207-564-7056

LOUIS MONIER
DIRECTEUR
LABORATOIRE DES TECHNOLOGIES ELECTROCHIMIQUES
ET ELECTROTECHNOLOGIES D'HYDRO-QUEBEC (LTEE)
TEL: 819-539-1401
FAX: 819-539-1409

MICHAEL WIGGIN
PROGRAM MANAGER
ENERGY SYSTEMS TECHNOLOGY IMPLEMENTATION
(ERL) CANMET
TEL: 613-996-8870
FAX: 613-995-9584

JIGAR V. SHAH
GESTIONNAIRE, DEVELOPPEMENT DES AFFAIRES
LINNHOFF MARCH LTD
TEL: 011-44-5656-50447
FAX: 011-44-5656-50581

MARTIN MCCALL
MANAGER
RESIDENTIAL AND COMMERCIAL TECHNOLOGY
CONSUMERS' GAS
TEL: 416-495-5004
FAX: 416-495-5230

DON ADKINSON
PRESIDENT
CANADIAN PHOTOVOLTAIC INDUSTRY ASSOCIATION
(CPIA)
TEL: 416-563-0539
FAX: 416-563-0455

DR. KEITH PRATER
VICE-PRESIDENT, TECHNOLOGY
GOVERNMENT & MILITARY/BALLARD POWER
TEL: 604-986-9367
FAX: 604-986-3262

RICHARD COTE
PRESIDENT
ASSOCIATION QUEBEC SOLAIRE
TEL: 514-438-2022
FAX: 514-438-3237

CHRISTIAN OUELLET
VICE-PRESIDENT
SOCIETE D'ENERGIE SOLAIRE AU CANADA
TEL: 1-242-1060/CELL: 594-1883
FAX: 1-242-1060

PIERRE GAUTHIER
DIRECTEUR, GROUPE DATECH
GAZ METROPOLITAIN
TEL: 514-598-3582
FAX: 514-598-3461

JAY BARCLAY
OFFICE OF ENVIRONMENTAL AFFAIRS
ENERGY, MINES AND RESOURCES CANADA
TEL: 613-996-4839
FAX: 613-995-5719

JEAN-MAURICE CHARRON
AGENT, TECHNOLOGIE DE LA PRODUCTION
ET DE LA MANUTENTION DE LA BIOMASSE
DIVISION DES ENERGIES RENOUVELABLES, CANMET
TEL: 613-996-6178
FAX: 613-996-9416

GUY RACINE
DIRECTEUR GENERAL
REGIE INTERMUNICIPALE DE GESTION
DES DECHETS SUR L'ILE DE MONTREAL
TEL: 514-849-1448
FAX: 514-288-4299

HERBERT CAMPBELL, M.A.SC;P.ENG.
ENVIRONNEMENT CANADA
HEAD, RESIDUE MANAGEMENT SECTION
WASTEWATER TECHNOLOGY CENTRE
CONSERVATION & PROTECTION
TEL: 416-336-4717
FAX: 416-336-4763

MARCEL RISI
PRESIDENT, DIRECTEUR GENERAL
CENTRE QUEBECOIS POUR LA
VALORISATION DE LA BIOMASSE
TEL: 418-657-3853
FAX: 418-657-7934

JACQUES BUREAU
CONSULTANT
ALBRIGHT & WILSON
TEL: 514-655-3007
FAX: 514-655-3007

HASSAN HAMZA
COAL RESEARCH LABORATORIES
TEL: 403-987-8214
FAX: 403-987-3430

CLAUDE GUERETTE
ENVIRONNEMENT CANADA
SYSTEMES DES TRANSPORTS
RESPONSABLE DES PROGRAMMES POUR VEHICULES LOURDS
TEL: 819-953-5610
FAX: 819-994-7762

TONY TAYLOR
DIRECTOR, TRANSPORTATION FUELS
EFFICIENCY AND ALTERNATIVE ENERGY BRANCH
ENERGY, MINES AND RESOURCES
TEL: 613-995-7300
FAX: 613-952-8169

VINCENZA ALLENGER
HEAD
HYDROCARBON CONVERSION SECTION
ENERGY RESEARCH LABORATORIES
TEL: 613-995-6392
FAX: 613-995-7868

JEAN-MARC CARPENTIER
PHYSICIEN, JOURNALISTE SCIENTIFIQUE
TEL: 514-982-0972
FAX: 514-279-9086

POSTER SESSION

"ENERGY AND THE ENVIRONMENT CONFERENCE"

SCHEDULE:

March, 20th 1991
from 10:00 a.m. to 5:00 p.m.

March, 21st 1991
from 8:00 a.m. to 3:30 p.m.



**CONFERENCE
ENERGY AND THE ENVIRONMENT
MARCH 20 AND 21, 1991
THE SHERATON CENTRE, MONTREAL**

**POSTER SESSION
SALON C**

- | | |
|---------------------------------|--|
| 1- INRS Energy: | The relationship between electrification and the environment: trace effects on fuels.
Gaétan Lafrance
Marc Hudon

1650 Montée Ste-Julie
Varennnes, Quebec
J0L 1E0 |
| 2 L.T.E.E. | Company display and poster unit
Donald Anger

600 de la Montagne Ave.
P.O. Box 990
Shawinigan, Quebec
G9N 7N5 |
| 3- Gaz Métropolitain | Storage of NGV by absorption
Richard Chahine
Roland Francoeur

Dept. of Physics
Université du Québec à Trois Rivières

Groupe Datech
Gaz Métropolitain

1717, du Havre
Montréal, Quebec
H2K 2X3 |
| 4- CIMA LNR
Consulting Group | Cogeneration
Sylvain Chenail

3385, King West
Sherbrooke, Quebec
J1L 1P8 |
| 5- Sonitech | Reverse Osmosis
Alain Blais

5625, Côte-de-Liesse
St-Laurent, Quebec
H4M 1V2 |

6- Ogilvy

Anaerobic Digester
Normand Mongrain
Mrs. Lanchi Nguyen

1, Place Ville Marie
Suite 2100
Montréal, Quebec
H3B 2X2

7- CRIQ

CFC Replacement
Michel Parent

333, Franquet
P. O. Box 9038
Ste-Foy, Quebec
G1V 4C7

8- Laval University
CANMET/EDRL

Waste Pyrolysis
Blaise Labrecque

Pavillon Adrien-Pouliot
Local 1503A, P. O. Box 2208
Ste-Foy, Quebec
G1K 7P4

9- CANMET/EDRL

CADDET Program
Robert Calinot

2082, Marie-Victorin blvd., suite 210
Varennnes, Quebec
J3X 1R3

10- CANMET

Mini-Hydro
Tony Tung

Energy, Mines and Resources Canada
580 Booth St.
Ottawa, Ontario
K1A 0E4

11- CANMET

Super Windows
François Dubrous

Energy, Mines and Resources Canada
580, Booth St.
Ottawa, Ontario
K1A 0E4

1version finale le mardi 19 mars 1991. AW

Conférence du Laboratoire de recherche
en diversification énergétique
le mercredi 20 mars 1991

allocution donnée par :

M.D. Everell
Sous-ministre adjoint
Secteur de la technologie des minéraux et de l'énergie
Énergie, Mines et Ressources Canada

CANMET et l'environnement

Introduction:

J'aimerais d'abord saluer toutes les personnes ici présentes et plus particulièrement, les représentants de l'Association québécoise pour la maîtrise de l'énergie, qui se sont associés à CANMET pour l'organisation de cette conférence.

Le thème de la conférence de cette année "L'énergie et l'environnement" ne pourrait être plus pertinent, compte tenu des préoccupations des canadiens à l'égard de leur avenir environnemental.

Les Canadiens se rendent compte jusqu'à quel point leur environnement est perturbé par les pluies acides, les menaces de l'effet de serre et les émissions nocives résultant de la production et de l'utilisation de l'énergie.

C'est ainsi que le gouvernement fédéral travaille en partenariat à trouver des solutions.

L'orientation de la politique fédérale sur la question de l'environnement est nettement tracée: le gouvernement a l'intention de faire du Canada un des pays les plus en harmonie avec l'environnement d'ici l'an 2000. Ce projet ambitieux demande une participation accrue des ministères et des laboratoires fédéraux qui travaillent en science et technologie. Mais on ne pourra réaliser cet objectif qu'avec l'étroite collaboration des secteurs industriel et universitaire canadiens, les gouvernements provinciaux et municipaux et les organismes de recherche étrangers.

CANMET a toujours joué un rôle de premier plan dans la recherche et

développement. C'est en 1907 que le gouvernement fédéral annonce l'établissement de la Direction des mines, le précurseur de CANMET. Presque 80 ans plus tard, en 1986, on désigne officiellement CANMET comme centre de technologie du gouvernement fédéral.

Les activités de CANMET, qui portent sur les secteurs des minéraux, des métaux et de l'énergie sont dorénavant plus axées sur le développement de techniques qui sont en accord avec l'environnement. Pour ses clients, CANMET veillera à développer des techniques qui minimiseront, sinon élimineront la pollution et qui répondront également à l'objectif à long terme d'un développement durable.

Or, si son rôle est bien connu lorsqu'il s'agit de trouver des solutions aux problèmes qui se posent aux industries canadiennes des minéraux et des métaux et des combustibles fossiles, il l'est moins dans le domaine des énergies de remplacement.

De fait, c'est en 1989 que CANMET augmente ses activités dans le domaine de l'efficacité énergétique et des énergies de remplacement. Suite à une réorganisation interne au ministère, on annonce l'intégration à CANMET de la Direction des technologies de l'efficacité énergétique et des énergies de remplacement et du Laboratoire de recherche en diversification énergétique.

CANMET - Énergie et environnement :

Permettez-moi de vous résumer la participation de CANMET dans le volet énergie et environnement.

Le mandat de CANMET consiste à diriger et à parrainer de la R et D dans les domaines des minéraux, des métaux et de l'énergie de façon à encourager l'innovation industrielle à l'échelle de la nation. Les travaux de recherche sont menés dans ses six laboratoires mais ses projets sont réalisés en étroite collaboration avec des partenaires industriels. CANMET parraine aussi des projets de recherche par l'attribution de contrats pour rencontrer ses objectifs en science et en technologie.

CANMET dispose d'un effectif de plus de 550 scientifiques, ingénieurs et techniciens répartis dans des installations de recherche au Québec, en Nouvelle Écosse, en Ontario et en Alberta. CANMET est l'un des plus grands centres de développement technologique au pays et sa priorité est de trouver des solutions aux problèmes qui se posent à l'industrie et aux établissements canadiens.

Pour orienter ses activités, CANMET a élaboré un plan d'entreprise qui propose sept orientations stratégiques pour ses activités futures. Dans le volet énergie et environnement, citons :

La protection de l'environnement et l'amélioration de pratiques de protection de la

santé et de la sécurité des travailleurs dans les industries clientes de CANMET.

Cette orientation comprend, autres autres :

- le contrôle des émissions en provenance des fonderies et des centrales électriques
- le traitement des effluents provenant des usines de traitement du pétrole, du charbon et des minéraux.

Une autre orientation stratégique veut soutenir une utilisation et une combustion propres et efficaces des combustibles, en se préoccupant, par exemple, du:

- développement des moyens nouveaux pour réduire les émissions de gaz carbonique par unité d'énergie utilisable, et;
- du développement des systèmes experts pour améliorer l'efficacité de la combustion des carburants

Developing technology to reduce harmful emissions and to use energy more efficiently has always been an important part of CANMET's work. We also ensure that every technology developed and promoted takes into account the potential impact on the environment.

For instance, EMR's R-2000 house developed in Canada in the 1980's was designed to be twice as energy efficient as a conventionally-built house. Further developments supported by CANMET have produced a more advanced house, which goes far beyond the R-2000 concept. Using the most energy efficient technology available, in combination with newly developed equipment which shows promise for the future, it has been possible to achieve four times the energy efficiency of a conventional house, or half of the energy use of an R-2000 house. The *Advanced House* was built in Brampton, Ontario in a project jointly sponsored by my department with Ontario Hydro, the Ontario Ministry of Energy and the FRAM Building Group. The *Advanced House* concept clearly shows what can be achieved, and will serve as a reminder that there are lots of opportunities still to be tackled in this key area.

D'autres projets de recherche qui visent à réduire les gaz qui sont la principale cause de l'effet de la serre et les pluies acides comprennent la mise au point du procédé de combustion sur lit fluidisé. CANMET, en collaboration avec le service public du Nouveau-Brunswick, a travaillé à la démonstration d'une chaudière à combustion sur lit fluidisé pour produire de l'électricité à partir de charbon à haute teneur en soufre et tout en contrôlant les émissions d'oxyde de soufre et d'oxyde d'azote qui sont à l'origine des pluies acides. Les émissions provenant de l'usine ont été réduites de 90 p. cent et de 45 p. cent respectivement par rapport à une usine de service public classique. Le projet a connu beaucoup de succès. En fait, les connaissances acquises ont été partagées avec ses partenaires de l'Agence internationale de l'énergie.

CANMET joue aussi un rôle important pour trouver des substituts aux réfrigérants avec chlorofluocarbures (CFC). Les CFC actuellement utilisés dans les systèmes thermiques détruisent la couche d'ozone quand ils sont relâchés dans l'atmosphère. En collaboration avec le Conseil National de la Recherche du Canada, Du Pont Canada Inc. et le Centre de Recherche industrielle du Québec (CRIQ), CANMET a identifié des réfrigérants prometteurs qui pourraient remplacer les CFC. Si l'on pouvait mettre au point des réfrigérants sans CFC, les thermopompes pourraient figurer plus considérablement dans les systèmes industriels et municipaux. Des recherches ont été entreprises pour établir les caractéristiques de nouveaux réfrigérants, et certains, en fait, pourraient offrir un meilleur rendement que certains CFC qu'ils remplacent.

CANMET tente aussi de diversifier et économiser les ressources énergétiques, telles les techniques reliées à l'efficacité énergétique et aux énergies de remplacement. La société C.-I.-L. de Toronto estime qu'en substituant la peinture automobile à base de latex, elle pourrait effectivement réduire sa consommation d'énergie lors du séchage des voitures fraîchement peintes. C'est pourquoi CANMET a subventionné ce projet. Mais à la suite d'essais, on s'est vite rendu compte que le nouveau procédé à base de latex procurait non seulement un meilleur fini, mais aussi, réduisait le montant de produits organiques volatiles dégagés dans l'atmosphère. General Motors du Canada a adopté ce procédé dans son usine de montage de camions GM à Oshawa. GM prévoit convertir ses diverses autres installations à ce procédé.

The recent tire fires in Hagersville, Ontario, and St-Amable, Quebec, have raised the profile of one of Canada's most challenging waste disposal problems: used tires. When tires are burned for one reason or another, they can pose a hazardous threat to the environment. Furthermore, this type of waste is difficult to manage because it is not biodegradable and does not decompose, is hard to grind and when buried, usually tends to make its way back up to the surface.

With support from CANMET, Laval University has developed a vacuum pyrolysis process that turns old tires into reusable products such as oil, gas, scrap steel and carbon black (which is used mainly in printing inks and as a pigment for rubber products). This type of project could potentially lead to a commercial-scale pilot plant for recycling used tires. Another avenue being explored by CANMET is the use of old tires in coke ovens to make metallurgical coke. We are also joining in a cooperative venture to explore a different process that could recycle the carbon from tires and other organic waste as liquid fuel.

CANMET, in concert with other Branches in Energy, Mines and Resources and its industry partners, has sponsored many projects in the alternative transportation fuels arena, such as ethanol, methanol, natural gas and hydrogen fuels. Just yesterday, we inaugurated a project demonstrating ethanol-fuelled transit buses. These buses, which will be in service in the City of Regina, represent the first large-

engine demonstration of 100 % ethanol in Canada. While this particular project is a technological first in Canada, the use of ethanol in passenger cars is not. In fact, a blend of ethanol and gasoline, called gasohol, has been produced and sold in Canada for over a decade in Western Canada by one of our partners in this project, Mohawk Oil.

I am sure one of the first things passengers will notice about these ethanol buses are the lack of black smoke and diesel odour typically associated with buses.

Work on efficiency and alternative energy technology is being expanded at our new Energy Diversification Research Laboratory, located just south of here in Varennes, Quebec. The lab's activities will include hands-on research in the areas of renewable energy and hybrid systems, natural utilization technologies and thermal energy storage and energy upgrading technologies such as advanced heat pumps and heat transfer technologies.

Le laboratoire de Varennes sera la première installation de recherche fédérale en énergie à être construite au Québec. Elle sera située dans un parc industriel qui compte parmi ses occupants des sociétés de recherche comme l'Institut National de la Recherche Scientifique et l'Institut de Recherche d'Hydro Québec. En choisissant Varennes comme emplacement, le laboratoire pourra entreprendre des projets de recherche complémentaire dans plusieurs domaines.

Entre-temps, le laboratoire entreprend ses activités de recherche dans des locaux loués jusqu'à ce que les installations permanentes soient complétées. Le laboratoire deviendra le centre canadien par excellence de R&D sur l'efficacité énergétique et les énergies nouvelles. Pour démontrer son engagement envers l'environnement et l'efficacité énergétique, CANMET a intégré dans les plans d'architecture un bon nombre de techniques de pointe et équipements qui rendront l'édifice très efficace au niveau de la consommation d'énergie. Par exemple, l'édifice sera isolé de façon optimale; deux chauffe-eau solaires domestiques seront installés pour chauffer l'eau d'usage quotidien; des fenêtres à basse émissivité seront installées sur la façade sud de l'édifice; un système de tuyauterie pour chauffer la dalle de béton du laboratoire sera alimenté à l'énergie solaire; et une enseigne qui annonce le laboratoire sera alimentée par un capteur photovoltaïque.

Finalement, un système photovoltaïque de 25 kilowatts sera installé sur le toit. Le laboratoire entreprendra des projets de recherche allant de la conception de systèmes à la recherche sur les matériaux.

Un des premiers buts du nouveau laboratoire est de diffuser les connaissances acquises grâce à la collaboration des industries participantes et des organisations scientifiques. C'est dans cet esprit qu'au nom du Canada, il administre CADDET, un programme de transfert d'information de l'Agence internationale de l'énergie. La

diffusion de fiches techniques et d'autre documentation dans tout le pays contribuera à faire connaître les réalisations de CANMET, des autres intervenants canadiens et des partenaires de l'Agence dans le domaine de l'énergie.

S'il est une chose sur laquelle tous s'entendront durant cette conférence, c'est bien sûr la solidarité dont nous devons tous faire preuve pour relever les défis environnementaux de notre décennie.

Le Plan Vert :

Depuis nombre d'années déjà, nous travaillons de concert avec l'industrie et les milieux universitaires à trouver des solutions à des problèmes liés à l'environnement. C'est pourquoi nous sommes enthousiaste vis-à-vis le Plan Vert récemment annoncé, un plan en sept points qui vise à assurer un environnement sain et qui contribuera à faire rayonner des principes de respect de l'environnement, d'économies d'énergie et de recyclage et d'efficacité énergétique.

Le Plan Vert vient renforcer le rôle de CANMET dans le domaine de l'efficacité énergétique et des énergies de remplacement. Diverses activités au sein du Ministère viendront d'ailleurs prêter main-forte aux activités de CANMET afin de favoriser la commercialisation et l'utilisation de techniques, pour emprunter de l'anglais, dites "VERTES".

CONCLUSION :

Le nouveau Laboratoire de recherche en diversification énergétique sera d'un précieux secours pour CANMET. Il témoigne d'ailleurs de la volonté manifeste du gouvernement d'investir dans l'avenir.

Parrallèlement aux activités du laboratoire, CANMET veut poursuivre des projets ambitieux et passionnants qui favorisent l'efficacité de procédés énergétiques et la diversification des sources d'approvisionnement.

Voilà une combinaison gagnante, d'un double point de vue. D'une part, elle nous aidera à relever les énormes défis qui nous attendent sur le plan écologique. D'autre part, elle nous incitera à rechercher un avenir énergétique plus diversifié, plus prospère et plus sûr pour notre pays, le Canada.

CANMET sera fier de s'associer à tous ses clients et partenaires pour mener à bien ses projets.

Si CANMET a joué un rôle de précurseur dans le dossier de l'énergie et l'environnement, ces poursuites indiquent bien qu'il lui reste encore beaucoup de pain sur la planche.

J'aimerais souhaiter à tous les délégués, une bonne conférence.

ALAIN STE-MARIE, ing.

NOTES BIOGRAPHIQUES

Diplômé de l'Ecole Polytechnique en génie chimique 1979 et de l'Université McGill pour un MBA en 1988.

Débuté carrière dans l'industrie pétrolière en environnement, en design des procédés et en production.

Depuis 8 ans chez Gaz Métropolitain où il a été successivement responsable des études de commercialisation, de la conception des programmes commerciaux et depuis 2 ans de l'assistance technologique pour la clientèle commerciale et institutionnelle à l'intérieur du Groupe DATECH.

Membre de nombreuses associations professionnelles, dont l'AQME. Il en est un membre fondateur, a été président de différents comités et depuis 2 ans président.

BIOGRAPHICAL NOTES

Graduated in 1979 from Ecole Polytechnique in chemical engineering and earned an MBA from McGill University in 1988.

Began his career in the petroleum industry in environment issues, in processes design and in production.

For the past 8 years, he worked with Gaz Métropolitain where he has been alternately responsible for marketing, commercial programs development and for the past two years, technological assistance to commercial and organizational customers within the DATECH group.

A member of numerous professional associations, he is a founding member of AQME, and he has chaired several different committees. As well, he has served as president of the association for the past two years.

"L'enjeu environnemental et ses effets sur le secteur de l'énergie"

ALAIN STE-MARIE

Résumé

Au-delà des grandes politiques environnementales qui sont encore en développement, l'heure est à la concertation énergie-environnement.

Il faut mettre en oeuvre, dès aujourd'hui, les actions et solutions face aux problèmes environnementaux connus.

"Environmental Stakes and their Effects on the Energy Sector"

Abstract

Beyond the environmental policies, which are still in development, the time has come to discuss more specifically energy\environment.

We must activate now actions and solutions towards environmental problems.

CLAUDE F. BROUILLARD

Président, Institut Canadien des Produits Pétroliers

Notes biographiques

M. Claude Brouillard a été nommé, en octobre 1988, directeur exécutif de l'Association pétrolière pour la conservation de l'environnement canadien. À sa création, en mars 1989, l'Institut canadien des produits pétroliers l'a nommé président.

M. Brouillard a vingt-cinq ans d'expérience acquise auprès de divers ministères fédéraux; il était en dernier lieu sous-ministre adjoint, à Emploi et Immigration Canada. Il a aussi accepté une affectation à l'étranger auprès de l'Institut interaméricain, chargé du développement agricole dans les Caraïbes.

M. Brouillard a reçu de l'université d'Ottawa un baccalauréat ès arts et un baccalauréat en philosophie en 1957. En 1972, il a suivi les cours de l'École nationale d'administration (ÉNA) de Paris, dont il est diplômé.

CLAUDE F. BROUILLARD

President, Canadian Petroleum Products Institute

Biographical notes

Mr. Claude Brouillard was appointed Executive Director of Petroleum Association for Conservation of the Canadian Environment in October 1988. In March 1989, at its inception, Mr. Brouillard was also appointed President of the Canadian Petroleum Products Institute.

Mr. Brouillard has twenty-five years of experience in various departments of the Federal Government, most recently as Assistant Deputy Minister, Employment and Immigration Canada. He also accepted an international assignment with the Inter-American Institute concerned with agricultural development in the Caribbean.

Mr. Brouillard attended the University of Ottawa and received a B.A. and a bachelor of Philosophy in 1957. In 1972, he attended and received a diploma from the National School of Administration (l'ÉNA) in Paris, France.

**IS THERE A FUTURE
FOR HYDROCARBON MAN?**

Remarks by
Claude F. Brouillard
President
Canadian Petroleum Products Institute

to

**Energy and Environment
Conference**

Sponsored by the
Canadian Centre for Mineral and
Energy Technology

Montreal, Quebec

March 20th, 1991

It's a great pleasure for me to speak today on behalf of the Canadian Petroleum Products Institute at this important conference on energy and the environment. In the title for these remarks I pose the question: Is there a future for Hydrocarbon Man?

(Slide with words: Is there a future for Hydrocarbon Man?)

Hydrocarbon man represents the species of homo sapiens that has emerged over the past century as we have become highly dependent on fossil fuels in our daily lives. In the next few minutes I want to look at how the future of that species will be affected by growing concern over the environment, and the need to conserve non-renewable resources.

(Slide - CPPI logo)

My perspective is that of the oil industry, which plays a vitally-important role in the energy sector of the Canadian economy. Our Institute represents what is referred to as the downstream side of that industry - the companies that purchase crude oil from the upstream end and refine it into motor gasoline, furnace oil, diesel and heavy fuel, aviation fuel, lubricating oils and other petroleum products used by millions of Canadians every day.

Slide - Montage of refineries, gas stations, products)

Every time you fill up your car at a service station, turn up the thermostat at home, board an airplane, ride in a bus, take delivery of a shipment, or buy a petroleum product you are benefiting directly or indirectly from the services and activities of the downstream petroleum industry.

We in the downstream industry are already taking action to deal with the impact of energy on the environment. We are initiating programs to protect soil, water and air from pollution, and conserve the non-renewable resource that is the present foundation of our business.

The theme of this conference - "Energy and the Environment" - may seem to be a very up-to-date one to many of us. But if we look at our history for a moment we will see that there has always been an element of tension between the environment and energy sources.

(Slide - desert scene)

One of the earliest sources of energy was wood. Even though this is a renewable source, the growth rate of trees

is often not fast enough to meet human needs.

In various parts of the world, woodlands have been levelled and deserts have taken over fertile land as people cut down trees to feed domestic fires, and provide charcoal for early industry.

(Slide - Steam locomotive with plume of smoke)

Then coal became the major energy source for the industrial revolution. With the development of the steam engine it became for a time the prime fuel for mechanized transportation by land and water, despite its problems of relatively low energy utilization and difficulty in handling.

Coal-burning locomotives and steamships had an extremely negative effect on the environment. The effects of coal emissions in the creation of acid rain were not fully known then.

But housewives knew that a passing train could transform a line-full of clean washing into a sooty mess, and neighbourhoods around busy rail depots had a smoke-filled atmosphere that would be unacceptable by today's standards.

(Slide - early oil lamp)

The birth of the oil industry had positive effects on the environment. It's hard for us to imagine now, but when petroleum deposits were first exploited more than a century ago, their major commercial application was to provide kerosene for illumination. This replaced the more expensive coal oil and whale oil that had been used in lamps up until then.

(Slide - picture of 19th century whaling)

In fact, the development of kerosene as a cheap source of illumination is credited with virtually wiping out the extensive nineteenth-century whaling industry in North America that was threatening to exterminate several species of whales. In one decade American whaling ships landed more than 41 million gallons of oil from sperm whales alone. Moby Dick, the great white whale, may have been spared from Captain Ahab's harpoon if only kerosene had been developed earlier!

Gasoline was first viewed as a useless by-product of making kerosene. Fortunately for the future of the oil industry, the internal combustion engine was developed at about the same time as the electric light bulb was replacing kerosene lamps as a source of light.

(Slide - early automobile)

As North America and the rest of the world fell in love with the automobile, gasoline was transformed from an unwanted by-product to the major focus of our industry.

This partnership of the petroleum industry and the internal combustion engine that began at the turn of the century had a profound effect on the daily lives of people around the world. It created what we might call hydrocarbon man.

Petroleum, a fuel that was extremely inexpensive compared with other energy sources, efficient and highly portable, proved to be the ideal form of energy for transportation.

(Slide - montage of modern auto, train, airplane, etc.)

The automobile, the airplane, the diesel locomotive and the motor vessel were developed extensively as a result of the availability and low cost of petroleum products, and these transportation modes revolutionized the way we lived.

Suburban living became possible for workers as the car made commuting convenient and relatively inexpensive. Travel became faster and safer, and was no longer the privilege of the very rich.

Industry and commerce boomed as rapid, low-cost transportation reduced distribution costs, and made mass production feasible.

Petroleum had other economic and social benefits. It created the era of cheap food as farms were mechanized to improve productivity, and petroleum-based fertilizers and pesticides were developed to increase yields.

For a time it looked as if oil had given us the age of plenty that our ancestors had dreamed of without having to pay any price.

Now we realize that we are paying a price for those decades of plenty.

(Slide - Environmental shot of trees, etc.)

We have become increasingly aware of the negative effects hydrocarbons can have on the environment.

We have been made painfully aware that oil is a non-renewable resource. Such events as the recent Gulf war show us how vulnerable off-shore supplies are, and awaken us to the urgent need to conserve this dwindling resource.

This conference is just one recognition of the fact that we have to take steps now to make up for the mistakes of the past, and to protect our children's future.

The petroleum products industry is keenly aware of its stewardship responsibilities, and is seeking to reduce or eliminate the negative environmental aspects of its activities through the careful management of its operations, the training of its workforce, and the creation of adequate emergency response resources.

Let me outline very briefly some of the actions the industry and the Institute are taking to deal with environmental concerns in a positive and practical manner.

(Slide - refinery)

The members of the Institute operate 25 refineries that process about 1.3 million barrels of crude oil a day.

One of the issues in this environmentally-conscious age is that the discharges from refineries may affect the quality of water in adjacent areas.

I am pleased to report that oil refineries in Ontario are now among the cleanest in the world in terms of the quality of the water discharged.

The results in Ontario have come about after 20 years of clean-up programs that have cost some \$350 million dollars in terms of equipment and other measures to clean waste waters of contaminants.

Our Institute members are now working on Refinery Waste Management Guidelines that will lead to similar clean-ups being achieved in other provinces across Canada.

(Slide - oil tanker)

Another area of environmental concern for our industry is the safe transportation of our products. One of our major initiatives has been in the area of tanker safety. The Institute is in agreement with the major recommendations of the report on Tanker Safety and Marine Spill Response released last year by the Brander-Smith public review panel established by the federal government.

The main thrust is, of course, prevention through such measures as building double-hulled vessels, but we also have to be prepared for the possibility of marine spills.

Last year, even before the report was issued, we had made our own investigation of these subjects, and established the need for more clean-up equipment.

(Slide - outline map showing depot locations)

The Institute announced last year a \$40 million co-operative program to establish marine spill equipment depots at strategic locations across the country.

These depots have boats, oil booms, absorbent materials and other equipment and supplies to deal with oil spills of up to 10,000 barrels. The co-operative approach means that the resources of more than one company can be brought to bear quickly if a spill occurs.

One depot is being located at St. David, near Quebec City, and has satellite stations to protect the lower St. Lawrence. Another depot is to be located at Dartmouth, on Halifax Harbour, another busy area for tanker traffic. Depots already exist at Sarnia and Vancouver.

In addition to these marine depots, we have 70 response centres to deal with land spills.

(Slide - Shot of Vancouver closed-cycle system)

Our members also operate storage and distribution depots for their products, and here again we are taking action to protect the environment from the vapours that result from fuel-transfer operations.

We are installing in a demonstration program in the Vancouver area closed-cycle systems to be used when tanker trucks are loaded. With these systems the vapours from the empty tanks are no longer discharged into the atmosphere, but are recovered for proper storage and disposal.

(Slide - modern service station)

The storage depots supply the familiar service stations, and here again we are taking steps to protect the environment. One of these measures is the used oil program which collects the waste oils that are a by-product of automobile maintenance, and recycles them in a way that not only protects the environment, but also helps conserve a non-renewable resource.

When many of these service stations were built, the approved method of underground storage of products was in plain steel tanks.

Now we have recognized the danger of leaks from aging tanks, and these are being replaced with fibreglass and corrosion-protected steel units.

(Slide - Shot of dense urban traffic e.g. 401)

Perhaps the greatest environmental concern over petroleum products, however, is what happens after they are burned in the internal combustion engine.

Experts say that pollution of our atmosphere is causing a greenhouse effect that will change our climate drastically if it is not checked, and they attribute a large part of that pollution to vehicle emissions.

This is the most complex issue for us to deal with, because so many different parties are involved. Harmful vehicle emissions can be reduced only if there is close co-operation between vehicle manufacturers and our industry, and public policies are developed that balance environmental concerns with the economic and social factors involved.

(Slide - shot of modern North American auto)

So far we have seen efforts by North American automotive manufacturers to improve fuel consumption and reduce emissions in response to such initiatives as the Corporate Average Fuel Efficiency (CAFE) program introduced by the United States government.

There have been other measures to make compulsory catalytic converters and similar devices that clean up emissions after they leave the engine.

The debate continues as to whether the answer is cleaner-burning engines, or more effective mechanisms for cleaning emissions. Another approach to the problem is the development of cleaner-burning fuels.

All these avenues are being explored, and advances are being achieved. But in many cases their benefits can be lost if car owners do not play their part by maintaining their vehicles to peak fuel efficiency, or if they seek to short-circuit the anti-pollution measures built into their cars.

Over the past few years lead has been eliminated from gasoline in Canada.

This is something that we take for granted now, but many other countries are still not committed to it to the same degree.

When Canadians travel to Europe they are surprised at the amount of leaded gasoline still on sale, and I read some months ago that when the Prime Minister's limousine was shipped to a certain foreign country for an official visit it could not be used because there was no unleaded gasoline available.

Now the petroleum products industry is moving to reduce sulphur levels in diesel fuel to 0.05 per cent by 1993, and other steps are being taken to remove benzine from motor gasoline.

I have not recited this litany of our activities in an effort to win accolades for the petroleum industry. We recognize that no matter how much we have achieved, there is much more left to be done.

The reason I am mentioning these programs here today is to indicate that for every environmental problem raised by petroleum products there is a solution, and the industry is already working on many of them.

(Slide with words:
ENVIRONMENTAL PROTECTION
WHO PAYS?)

These programs give some indication of what can be done in this area of environmental protection. The two key elements are co-operation and large-scale expenditures. And the major question is: Who pays?

When it comes to resolving environmental concerns, there are no low-cost and easy answers. We have estimated, for example, that it will take an investment of more than \$500 million to achieve the removal of benzine from motor gasoline. The reduction of sulphur in diesel fuel will require expenditures of almost one billion.

These costs are a massive financial challenge for a business that does not benefit from the windfall profits or lucky oil strikes associated in the public mind with the oil industry.

(Slide with words
AVERAGE RETURN ON INVESTMENT
1985-89
3.7 per cent)

It may come as a surprise to many people to learn that over the past five years the average return on investment of the downstream oil industry has been only 3.7 per cent.

This means that the industry does not have vast profit margins to pay for massive investment in new plant required to meet environmental concerns.

It is easy to say that the industry should pay for changes required to meet environmental concerns, but the industry has only one source for its revenues - the consumer.

So when you say the industry must pay, what you are really saying is that its customer, the consumer, must foot the bill.

It is equally easy to say that governments should pay for the changes. But again, governments have only one source of funds - the taxpayer.

(Slide with words
The question is:
Not WHO will pay, but
HOW the public will pay)

The choice, therefore, is not so much who will pay, but how the public will pay - either at the gas pump or in their taxes.

Experience has shown us that there are no cost-free solutions to complex environmental issues.

As we meet in Montreal for this conference on Energy and the Environment, it is appropriate to look to the future of our industry over the next few decades.

(Slide with words:
THE FUTURE
Alternate fuels)

We are already seeing, especially in the U.S., the development of alternative fuels for motor vehicles. Replacements for the petroleum-fuelled internal combustion engine that has powered the transportation industry for most of this century are being devised, designed, and tested in research labs around the world.

Our members are already looking at the feasibility of using propane, natural gas and methanol to augment the use of petroleum products.

Their service station network is providing the distribution network for propane and natural gas.

One recent article in the *Globe and Mail* noted that there are now 5,000 stations across Canada equipped to provide propane to motorists, and 120 natural gas stations. Only with a distribution network as extensive as the one our industries offer can alternate fuels gain acceptance with the motoring public.

The impact of alternate fuels as energy sources is already measurable. In 1979 oil represented 40 per cent of Canada's energy market. A decade later that figure was down to 30 per cent.

(Slide with words
Benefits of petroleum products
 . Economical
 . Efficient
 . Convenient

second largest nation in the world, transportation costs have an inordinate impact on the prices of our exports.

But this does not mean that the petroleum products industry can operate into the next century in the same way as it has over the past one.

Over time we see ourselves evolving into more a broadly-based energy industry in response to changes such as those resulting from new breakthroughs in alternate fuels and automotive technology, and other advances in the area of transportation.

The negative environmental impacts of our industry are clearly identified and acknowledged.

But they can be alleviated through measures such as the ones we already have under way - greater care in the refining and transportation of our products, and the development of cleaner-burning fuels.

The challenge to us is to develop the technology, the guidelines, and the means of paying for them. As I indicated earlier, the downstream petroleum products industry does not have a return on investment sufficient to finance on its own the massive expenditures required.

We must also recognize that petroleum resources are non-renewable, and the more accessible of them are being depleted. This imposes on all of us a responsibility to conserve these resources, and to augment them with alternate fuels.

This can mean everything from expanding on the use of gasoline-methanol mixtures, to changing our lifestyles to make them less dependent on the privately-owned automobile, which is the least efficient transportation use of petroleum products.

The petroleum products industry has played a key role in the development of growth of Canada in the past.

(Slide - CPPI logo)

In closing, I want to assure you that we are committed to continuing our contribution to Canada's prosperity as we move forward into an environmentally-sensitive and resource-conscious future.

MAURICE HUPPE
Executive Vice-President
Technology, International Affairs and IREQ

Biographical notes

Mr. Huppé was born in Thetford Mines. He attended high school there, then went to the Ecole Polytechnique de Montréal where he earned a degree in mechanical and electrical engineering in 1955.

Upon graduating from university, Mr. Huppé was hired as an engineer in the Montreal office of the Shawinigan Water and Power Company. When the company was taken over by Hydro-Québec in 1965, he became the Assistant Manager, Distribution in Trois Rivières. He was appointed Chief of Operations at Headquarters in 1968, and then promoted to Manager of the Drummondville Section of the Richelieu Region in 1971. In early 1973, he became Acting Director of the Richelieu Region. At the end of that year, he was appointed Director of the Abitibi Region. In June 1978, he became Director, Programming and Control in Installations.

In August 1979, Mr. Huppé was appointed Director of the Maisonneuve Region. On January 1, 1985, he became Vice-President, Maisonneuve Region. On May 18, 1987, he was promoted to his current position, that of Executive Vice-President, Technology, International Affairs and IREQ.

Mr. Huppé is Chairman of the Board of Hydro-Québec International; he is also Chairman of the Board and President of Nouveler Inc. and Chairman of the Board of the Centre d'Innovation sur le transport en énergie du Québec (CITEQ). He is on the Executive of the Canadian National Committee of the International Conference on Large High-Voltage Electric Systems (CIGRE) and on the board of the Montreal Centre of Initiative in Technology (CITEC). He is President of the Mouvement international du loisir scientifique et technique (MILSET) and President of the Canadian Electrical Association (CEA).

Mr. Huppé also sits on the board of the Société pour la promotion de la science et de la technologie, the Innovation and Technology Management Council of the Conference Board of Canada, the Centre of Excellence for Economics and Energy Management, the International Affairs Committee of the Hydrogen Industry Council, the Japan Society, the Order of Engineers of Quebec, the Chambre de commerce du Montréal métropolitain, the Club d'électricité de Montréal, and the Association des diplômés de l'Université de Montréal and Association des diplômés de Polytechnique.

"Position of Canadian industry on electrical power and the environment."

MAURICE HUPPÉ

Abstract

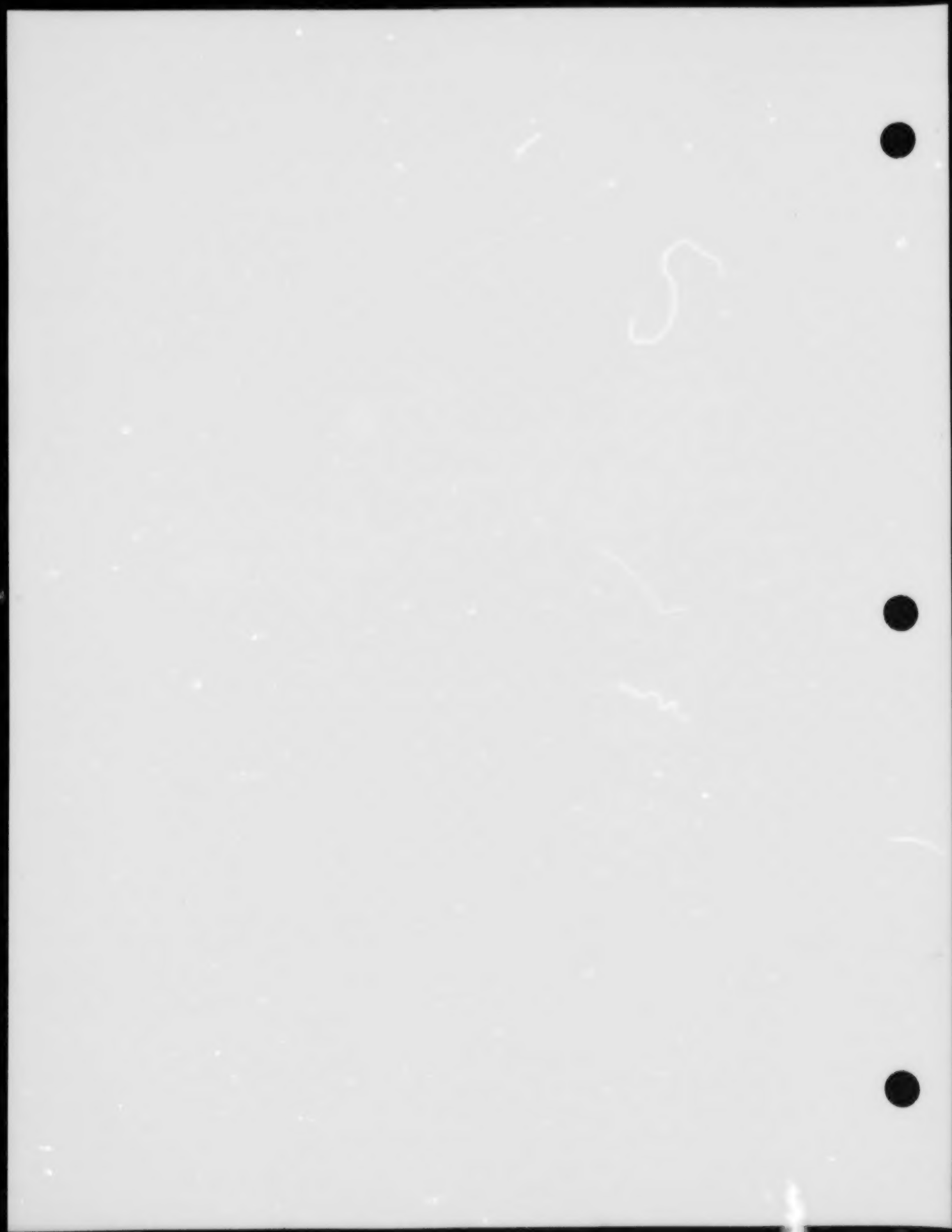
The 35 member companies of the Canadian Electrical Association (CEA) are faced with a common challenge: "How to meet electrical power demand at an affordable cost while reducing potential environmental impact and fostering acceptance of the CEA's projects within the community?".

Mr Huppé will talk about the leadership role played by the CEA. He will also discuss the efforts being made and the solutions that have been proposed to meet this challenge.

**POSITION OF CANADIAN INDUSTRY
ON ELECTRICITY AND THE
ENVIRONMENT**

Mr. Maurice Huppé
President,
Canadian Electrical Association

Energy and Environment Conference
March 20th, 21st 1991



Mr. Jake Epp, Minister of Energy, Mines and Resources Canada;

Mr. Robert De Cotret, Minister of the Environment;

Mr. Marcel Danis, Minister of State for Youth and Minister of State for Fitness and Amateur Sports;

Mr. Stelios Pnevmaticos, (which one is right? Request has him with a u and this page has him with a v - the u is more likely in a Greek name...) Chairman of the conference, and Director of the Laboratoire de recherche en diversification énergétique;

Mr. Marc Denis Everell, Assistant Deputy Minister, Department of Energy, Mines and Resources.

The theme selected for this conference and the number of papers scheduled for the next two days bear eloquent witness to the undeniable link between energy and environment.

For millenniums, energy has formed the basis of human civilization. At the dawn of time, man discovered that fire warmed him and allowed him to cook his food. Later, fire helped him make the tools with which he shaped his world.

But just as our long-ago ancestors discovered that wood fires filled their caves with smoke, we too have known - for centuries - that the production and use of various forms of energy have a price: namely the degradation of our environment.

The companies I represent produce electricity. This form of energy is, by definition, essentially non-polluting, at least at its point of use. This feature has contributed substantially to improving the quality of our environment, especially in urban centres. The first industrial cities which, in the last century, used coal as their prime source of power, were obvious examples of the disastrous impact of producing energy without controlling its by-products.

While the use of electricity offers every guarantee of health, its production from sources such as coal, oil, gas, water, uranium, and even the sun and wind, necessarily has an impact on the environment.

It should be added that conveying this electricity to its point of consumption also results in a certain depredation of natural and human habits. High-voltage transmission lines and local distribution systems provoke negative reactions, on the one hand for esthetic reasons, but also - and this is more recent -

because of the possible repercussions on human health due to electrical and magnetic fields.

This last issue is taken very seriously by the companies I represent. Studies conducted to date have yet to demonstrate any direct link between these fields and the incidence of disease. Nevertheless, sufficient questions persist to warrant more exhaustive research.

■

The environment will be the challenge of the 21st century. Canadian electrical companies are aware of this, hence the dilemma now facing them.

Indeed, how does one reconcile the need to produce electricity in order to maintain our economy and, consequently, our standard of living with the realization that its production has an impact on the environment? The dilemma can also be expressed in other terms: what price should one pay to continue to enjoy the benefits of electricity?

In the next few minutes, I will discuss the efforts of the members of the Canadian Electrical Association to make as fair an assessment of this environmental price as possible.

■

But before we get into this subject, I would like to correct any impression you may have gotten from a superficial glance at the figures on the production and consumption of electricity in Canada.

It is accurate that Canada is one of the top five producers of electricity in the world. Its production is comparable to that of far more populated countries, including Germany, France, Great Britain and even the People's Republic of China! It is therefore not surprising that in terms of per capita consumption we are second only to Norway.

Canada's harsh climate offers some explanation of these facts, but the main reason is connected rather with the very strong presence, both in Canada and in Norway, of industries whose most salient feature is that they consume a lot of electricity.

Canada's abundant natural resources and the relatively low cost of electricity have attracted companies for whom energy is a major factor in their operating costs. We should therefore not be too quick to conclude that Canadians waste electricity. In fact, a sectoral analysis reveals that Canada's performance is comparable to that of other industrialized nations.

This fact is relatively unknown. I think that it is in the interest of the electrical companies to explain why, on a per capita basis, we use considerably more energy than other countries.

In recent decades, we have taken up a formidable challenge: that of equipping Canada with an almost flawless production, transmission and distribution system, in spite of climatic and geographical constraints that are unique to our country.

Which is why I am very confident when I am asked whether the Canadian electrical industry can continue to produce this kind of power and still protect our natural heritage. I would even go so far as to say that I am downright optimistic.

However, there is one condition that must be met if the efforts we are making to meet this challenge are to bear fruit. This condition is that we win and keep the trust of the people.

■

This issue of trust - or if you prefer: credibility - is very important, even essential.

In all honesty, I have to tell you that the reputation of the major electrical producers of the past as organizations with little interest in environmental conservation is not altogether undeserved.

The construction of mega-projects, which included hydroelectric dams and coal and nuclear-powered generating stations, made us look like giants, capable of advanced technological feats but incapable of showing concern for the survival of fish, birds and plant life. If you will, we probably seemed like a bull in a china shop...

And sometimes this was true. Nevertheless, in recent years, tremendous efforts have been made to preserve our natural heritage. We therefore find it somewhat upsetting that part of the population feels that the Canadian electrical companies are not sufficiently concerned with environmental conservation.

Indeed, a survey carried out in late 1990 by the highly reputed Angus Reid firm shows that four out of ten Canadians feel that the companies that produce electricity from nuclear sources are not concerned enough with their impact on the environment. A comparable proportion have the same opinion about hydroelectric power production. This last proportion has grown by 9% since last year.

These figures worry us, even though, from another perspective, the electrical companies are rather well regarded compared to other industries.

In recent years, Canadians' awareness of environmental issues has grown considerably. The same survey shows that a significant proportion of people rate water and air pollution, waste management, depletion of the ozone layer and the disappearance of animal and plant species as crucial issues.

Fortunately, the same survey offers an optimistic outlook. 42% of Canadians - against 31% in 1989 - think that the general condition of the environment will improve between now and the year 2000.

We hope we can contribute to this improvement which everyone yearns for. We know - and we affirm it daily - that there can no longer be any question of brushing aside environmental issues in the name of economic growth. That era is long gone.

Unless we can reverse this trend, our governments may be forced to pass multiple laws and regulations, resulting in rigid control of our actions. In such a context, we would lose the flexibility that allows us to offer Canadians the best possible energy options.

Across the country, electrical companies are stating very clearly that they are ready to meet the challenge of supplying reliable power at an acceptable price, while respecting the environment.

■

Because it is a challenge facing all of the power utilities, even though production conditions vary considerably from one part of the country to the next, the Canadian Electrical Association therefore has a crucial role to play.

Our association represents 35 utilities in ten Canadian provinces. The assets of these companies exceed 100 billion dollars and they employ approximately 100,000 Canadians. The technical means and expertise of this network make it a leading industry on all levels.

Working through the Canadian Electrical Association, the utilities have equipped themselves with an important environmental policy. An environmental policy committee set up by the Board of Directors has formulated a series of principles and strategies to guide the companies and help them meet their commitment to maintaining only the strictest environmental practices. The Canadian Department of the Environment is involved in this process.

The Association has also developed practical tools, in the form of inspection guides, so that its members can make sure that they are following the rules of practice. Our plan of action in the area of research and development deals specifically with the

issues of environmental impact and electrical efficiency. In fact, the Association is a well-known leader in matters of energy conservation and has successfully implemented residential, commercial and industrial programs of its own.

The Canadian electrical industry plays a major role in shaping Canada's environmental policy, both directly, through the resources of its members, and indirectly through the Association.

Through the Canadian Electrical Association, the industry participates in consultations regarding the development of a management plan for nitrogen oxide and volatile organic compounds. Our input helped the federal government write its Green Plan and we are helping to develop Canada's position on a global agreement for control of atmospheric emissions responsible for the greenhouse effect.

In the context of creating a consensus among society's partners on the crucial issue of linking energy production with environmental conservation, the association I represent and all its members are considered major players.

■

Now let's identify these environmental impacts.

The major problems facing society are well known: acid rain, the greenhouse effect, urban smog, the storage of radioactive wastes, and ecosystems disturbed by the development of hydroelectric complexes.

Heading the list, as one might expect, are the atmospheric emissions of thermal generating stations that use fossil fuels. These contaminants - sulphur dioxide, hydrogen oxides and carbon dioxide - are the main focus of reduction programs. In those areas of the country that depend on fossil fuels, these issues are extremely important.

In fact, there is a world consensus that has identified these gases as priorities in the development of planet-wide programs for the control of atmospheric contaminants.

Sulphur dioxide, which is the main culprit in acid rain, was initially the focus of a management strategy between the provinces and the Canadian government. Since then, Canada and the United States have hammered out an agreement to limit emissions, which is about to be signed. The management of hydrogen oxide emissions is also the subject of an international protocol by virtue of which Canada will reduce its emissions to 1987 levels by 1995. This commitment has led to the development of a joint federal and provincial management program for hydrogen oxides and volatile organic compounds, which is nearing completion.

Global warming caused by the greenhouse effect is another major issue. Carbon dioxide emissions were considered a relatively inoffensive by-product of combustion until recently. Not so long ago, engineers said that ideal combustion - meaning non-polluting - would have carbon dioxide and water vapour as its sole residues. But the data has changed. Canada has committed to limiting its emissions to 1990 levels by the end of the century, thus endorsing the work of the United Nations commission responsible for developing the plan of action and appropriate protocols.

■

Fortunately, compared with other countries, the Canadian electrical industry is doing quite well with respect to the emission of contaminants into the air. Indeed, more than three quarters of our electricity is derived from hydroelectric and nuclear sources.

However, these sources of energy also have an impact on the environment. The issue of storage of radioactive wastes is of great concern to the public. Currently, irradiated combustibles are stored on-site in concrete pools and silos. In the short term, these methods pose no real problem. However, because of the nature of some of these wastes, we have to think in the long term.

The public's fears with regard to this form of electrical production is due, at least in part, to the lack of a solution to the storage of radioactive wastes. Atomic Energy of Canada Ltd. recently proposed burying these wastes deep in the rock of the Canadian Shield. However, authorization is as yet unforthcoming. Recycling irradiated wastes could also be considered, but here again the problems are numerous and complex.

Energy produced from hydroelectric sources is not exempt from environmental impacts either. It requires inundating large areas, with the resultant destruction of wildlife habitats and land use restrictions for human communities, especially native communities.

The contamination of water reservoirs with mercury, even if it is only temporary, also poses serious problems.

These relatively new considerations mean that opposition to major hydroelectric installations is growing. Newfoundland, Quebec, Manitoba and British Columbia all show major potential for hydroelectric development. Yet development of this potential hinges entirely on the outcome of some very difficult debates.

In parallel, daily concerns are also demanding attention. The Association and its members have had to make some concrete decisions regarding: the defoliants used to maintain the rights-of-way in our transmission system, the pentachlorophenol that coats the poles in our distribution system, and the elimination of PCBs which are currently in storage or still in use.

Generally, the Canadian electrical industry concurs completely with the observations of the Commission mondiale sur l'environnement et le développement and subscribes to the guiding principles of sustainable development.

■

But it is not enough to identify the problems. We must also try to provide answers.

To find effective and realistic solutions to these many problems, the electrical companies have adopted a triple approach: predict, prevent, mitigate.

To predict the environmental impact of development projects as accurately as possible, our members have developed highly advanced analytical tools that take a number of physical and human factors into account. A comparison of the value which these projects represent for society and the scope of their impact on the environment are a part of this evaluation.

The environmental impact analyses for all of these projects are systematic and conducted with a great deal of objectivity, regardless of what some of the public thinks. The media monitor our information and our actions very closely. Aside from the strict laws and regulations to which we are subject, we also have to pass public muster.

Because it would be illusory to think that the public takes our word for it when we say that our projects are socially and economically acceptable, the power utilities must be honest and frank when it comes to explaining the issues involved in building new transmission installations or production centres.

We therefore rely on communication and consultation strategies that are based on honesty and transparency to convince impartial observers of the objectivity of our process. We do good work and we want everybody to know it.

The second element of this strategy of acceptance is to prevent environmental problems before they occur.

To meet requirements, we must continue to build new generating stations and to operate the ones we already have, even those built at a time when today's standards did not apply. Impact studies are therefore an ideal tool for ensuring that our projects are in compliance with both current laws and regulations as well as the

company's commitments regarding economically feasible mitigation measures.

In the case of thermoelectric generating stations that use fossil fuels, our members use the most recent technological solutions to reduce the emission of pollutants. Many of these technologies were developed here.

A low hydrogen oxide and sulphur dioxide coal burner developed by TransAlta is currently being tested in Canada and the United States. It is an advanced technology that reduces both operating costs and the emission of contaminants. Another case in point is the thermal generating station at Tracy, Québec which has been powered with a low-sulphur fuel since 1989 and is slated for conversion to natural gas in the near future. For its part, Ontario Hydro, which is considered a world leader in matters of nuclear efficiency and safety, has developed an original technique for replacing the tubes in its CANDU reactors. Finally, Hydro-Québec has conducted some very thorough studies on the mercury contamination of water as well as the impact of harnessing rivers on aquatic habitats.

■

Yet despite our efforts, we will probably never be able to produce electricity without impacting the environment in some way. One of the solutions is therefore to produce less while ensuring that consumers' needs are met. This is the strategy behind electrical efficiency.

Over the next decade, six billion dollars will be invested in electrical efficiency programs for the residential, commercial and industrial markets. The prospects for the future are wide open. The power companies are resolute in their commitment to achieving what may be termed an ambitious objective, because it involves a significant change in mentality.

It is no longer a question of simply distributing electricity today without consideration for its environmental impact, without a care for exhausting resources and without listening to our clients' concerns for the growing cost of energy. The concept of limitless abundance has no basis in reality today.

By adopting this approach, the members of the Canadian Electrical Association - which incidentally is celebrating its 100th anniversary in 1991 - are manifesting their firm intention of preserving this resource - which is essential both to the economy and to the welfare of all Canadians - for generations to come.

■

In the last few minutes, I have attempted to draw an honest picture of the situation.

I cannot tell you that producing electricity, regardless of its source, will one day be totally without impact on the environment. However, what I can say is that the companies I represent here have made a strong commitment to protecting the integrity of our environment.

You will say that it is normal that these companies should be leaders in terms of respecting standards, because most of them are publicly owned. But there is more. We are also business enterprises and, in this respect, we must integrate our clients' concerns with our operating strategies. It is as much a matter of common sense as it is of social responsibility.

One of the major elements that will allow us to fulfill our duty to help build a better world is the credibility that I mentioned earlier. If we are unable to convince the public that we are making all the necessary efforts given the circumstances, we will not be in a position to deploy all of our technical means effectively, including the ones that we are currently developing to offset the impact of our operations.

I hope that I have managed to convince you that the electrical companies are aware of their responsibility to protect our environment and that they intend to do everything in their power to be able to continue to fulfill their mission while protecting the resources that our children will need in the future.

Thank you.

■

JOHN S. KLENAVIC

Notes biographiques

M. John Klenavic s'est joint récemment à l'Association canadienne du gaz à son bureau d'Ottawa en qualité de vice-président des relations avec le gouvernement.

Il est ingénieur diplômé de l'université Queen's.

Auparavant, M. Klenavic a oeuvré pendant 20 ans au gouvernement fédéral dans un certain nombre de postes, entre autres à la Direction générale de la protection de l'environnement, au Bureau fédéral d'examen des évaluations environnementales et au ministère des Affaires indiennes et du Nord pour le Programme de l'environnement du Nord. Plus récemment, il a été secrétaire à l'Office national de l'énergie et directeur général à la Réglementation des pipelines, et a travaillé avec le Service des politiques du ministère d'Environnement Canada.

Biographical notes

John Klenavic recently joined the Canadian Gas Association as Vice-President Government Relations in the Association's Ottawa Office.

He is graduate of Queen's University and a registered Professional Engineer.

Prior to joining CGA, Mr. Klenavic spent some twenty years with the federal government in a number of energy and environment related appointments, including the Environmental Protection Service of Environment Canada, the Federal Environmental Assessment Review Office, and the Northern Environment program of the Department of Indian and Northern Affairs. Most recently he was with the National Energy Board, serving as Board Secretary and as Director-General Pipeline Regulation, and with the Corporate Policy Group of Environment Canada.

"The Impact of Natural Gas On The Environment"

JOHN S. KLENAVIC

Abstract

Natural gas, the most environmentally-benign fossil fuel is assuming an increasingly important role in Canada's energy future. With no sulphur content and two-thirds less carbon dioxide emissions than coal, processed natural gas is an energy alternative that can help combat pollution and global warming. The efficiency of the overall natural gas process further contributes to the environmental desirability of this fuel. Developments in the natural gas industry, including cogeneration and technological advances in high efficiency equipment are aimed at conserving our energy resources.

IMPACT OF NATURAL GAS ON THE ENVIRONMENT

BY: Mr. John S. Klenavic
Vice-President
Canadian Gas Association

March 20th-21st, 1991

THE IMPACT OF NATURAL GAS ON THE ENVIRONMENT

* Title Slide: Natural Gas and the Environment

Good morning. I'm very pleased to be part of today's program and to have this opportunity to talk to you about natural gas -- its potential environmental benefits and the increasingly important role we expect it will play in Canada's future.

But first, allow me to give you a bit of background.

* Slide: The Economy

Canada is the world's fourth largest exporter of natural gas. In fact, our country's natural gas industry generates some \$3 billion annually in export revenues, employs over 30,000 Canadians, and supplies 28.5 per cent of the nation's energy demand. Over 3.8 million residential, industrial and commercial customers are turned on to natural gas.

Our pipeline and distribution network -- 250,000 kilometres of pipe altogether -- is among the safest and most efficient in the world. The system gathers natural gas from western Canadian processing plants, transports it across the country and delivers it to those 3.8 million customers.

And we expect that this impressive productivity will only increase as Canada's supply of natural gas is abundant and expected to last well into the future. Estimated proven gas reserves are 85 to 95

trillion cubic feet, with potential reserves of an additional 325 to 335 trillion. To put these numbers into perspective, we produce about 3.3 tcf a year in Canada, including exports of 1.4 tcf.

*** Slide: Bincher's Pond**

Besides being plentiful, natural gas is also the cleanest-burning fossil fuel. This distinction is especially significant in a world facing environmental challenges of an unprecedented magnitude. As we assess our energy options and seek solutions to complex environmental problems, the role of natural gas is becoming increasingly important.

In fact, some of you may have seen our advertisement and already be aware of what natural gas has to offer the environment. If that's the case, you probably also recognize this little fellow from Bincher's Pond or his twin brother qui habite l'Etang Marcoux. As environmental authorities in their own right, I'm sure they would both agree with the conclusion reached by that other famous frog, Kermit -- "It's not easy, being green".

*** Slide: Natural Gas. The Natural Choice**

The Canadian gas industry is certainly conscious of the environmental stress linked to all stages of the energy cycle and is actively working to find credible solutions. While the industry supports a balanced energy policy that uses all of Canada's resources efficiently and wisely, research shows that the increased use of natural gas can help combat some of the critical

environmental problems we're facing today -- in particular, acid rain, urban smog and global warming.

*** Slide: Acid Rain**

Let's begin with acid rain. The increased use of natural gas can help us in our fight against the emission of sulphur dioxide and oxides of nitrogen. This is because while the combustion of all fossil fuels produces nitrous oxides, processed natural gas contains no sulphur and thus contributes less to acid rain.

In Canada, sulphur dioxide is produced mainly by non-ferrous smelters or electricity generating stations that burn high sulphur coal. The co-firing of natural gas with less environmentally acceptable fuels such as high-sulphur coal or heavy-fuel oil can cut acid rain emissions and increase fuel efficiency. Several electric power plants in the United States have done just that. By combining natural gas with coal or oil, they have substantially reduced their sulphur dioxide emissions.

Given the fact that the Federal Green Plan proposes to cap sulphur dioxide emissions, we can reasonably expect even more industrial users, and perhaps power generating stations, to convert to natural gas. This would cause a further increase in the demand for this environmentally-desirable fuel, at a time when current demand already exceeds the "normal" rate and is expected to continue to do so for at least the next decade.

Other natural gas technology under development will improve the efficiency and desirability of natural gas even more. Natural gas fuel cells, for example, convert the chemical energy of gas directly into electricity and usable heat without an intermediate combustion step. There are no nitrous oxides released, and releases of sulphur dioxide and greenhouse gases are potentially much below those of other fossil fuel-based processes.

*** Slide: Smog**

Let's move on to the issue of urban smog. Some consider smog to be the most serious air quality problem remaining in many areas of the country, and the federal and provincial governments are in the process of developing initiatives to help alleviate the problem. Plans are to reduce allowable emissions of nitrous oxides and volatile organic compounds, most of which are released by motor vehicles.

Compared to other transportation fuels, natural gas has the potential to reduce the level of volatile organic compounds. Methane, the primary component of natural gas, is a relatively stable element which does not participate in the reactions leading to smog. Since any natural gas leaks or combustion contribute little to the release of reactive hydrocarbons, natural gas emerges as a desirable fuel for vehicles and industry. Converting a car from gasoline to natural gas can reduce its carbon monoxide emissions by 50 per cent and reactive hydrocarbon emissions by up to 40 per cent.

Right now, there are over 23,000 natural gas vehicles on the road in Canada. With the introduction of a home refuelling appliance, the number of gas vehicles is expected to rise dramatically.

As well, more people have converted their commercial fleets of cars and trucks to natural gas. Several municipalities, including Toronto, Mississauga and Hamilton, are also running natural gas buses with their transit fleets. They're being tested for comfort, convenience, cost and emissions. Results so far are very encouraging. Two Canadian-made natural gas buses, now part of Brooklyn, New York's transit fleet, already meet current Environmental Protection Agency emissions standards.

*** Slide: Global Warming: The Greenhouse Effect**

Let's now look at the third environmental concern -- global warming as a result of the greenhouse effect. Higher concentrations of carbon dioxide and other trace gases trap energy and radiate most of it back to earth, increasing the temperature at the earth's surface. Although the significance of the greenhouse effect is not yet fully understood, most experts seem to agree that an increase in the average earth surface temperature could, over time, seriously disrupt agricultural production and raise sea levels, causing flood and fresh water contamination.

Since the industrial revolution, the burning of fossil fuels has raised trace gas levels in the earth's atmosphere beyond levels

that occur naturally. Rapid post-war industrial activity accelerated the build-up even more, but with the added influence of new synthetic gases like CFCs.

We know we must slow down the accumulation of these gases to retard the greenhouse effect, but we also know that the world's demand for energy keeps increasing. So how do we reconcile these facts? Part of the answer could be to compare the greenhouse gas contribution of different energy forms and choose the least harmful fuel.

That kind of assessment is difficult and complex because there are dozens of trace gases involved. However, although other gases contribute their fair share, carbon dioxide, the product of all combustion, is generally considered the principal greenhouse gas. Estimates are that it accounts for about half of the total problem. But not all fossil fuels produce the same amount of carbon dioxide.

*** Slide: Comparison**

Natural gas, because it produces the lowest level, again emerges as the most attractive choice. Coal emissions produce 79% more, heavy fuel oil 65% more, and gasoline 37% more carbon dioxide than natural gas.

*** Slide: Comparison**

Methane is a greenhouse gas, too. Estimates are that it contributes 20% to total greenhouse warming. The natural gas that is piped to your home, office or plant is 95% methane, and if

released unburned, could be a factor. However, it is natural sources which release the majority of methane to the atmosphere. The natural gas industry ranks far below swamps and ruminants such as cattle and sheep in this regard. In fact, natural gas leaks are extremely rare and are estimated to account for under two per cent of the total worldwide release of methane. The natural gas industry has, over the years, put top priority on preventing leaks in its production and distribution system. This has been emphasized for reasons of safety and economy. Today, the environmental benefits of preventing leakage add to the importance the industry places on securing its system.

*** Slide: Conservation and Efficiency**

There is no quick and easy solution to the serious environmental issues that abound but it is obvious that immediate action is needed. While we must all acknowledge that no form of energy is entirely benign, I have shown you today that natural gas can play an increasingly important role in combatting pollution and global warming. Natural gas may not be the ultimate solution to our woes but it is definitely the preferred alternative while the world continues to search for another remedy.

More prudent use of our energy resources is clearly another step in the right direction. The Canadian gas industry has long been a supporter and promoter of energy conservation. By using energy more efficiently, we will do less damage to the environment.

While energy conservation, improved energy efficiency, and the development of non-polluting energy forms will help, it will take a long time before the benefits of such measures are felt. However, the increased use of natural gas, as a replacement for other fossil fuels, will immediately reduce harmful emissions.

*** Slide: New Developments**

The Canadian natural gas industry has made some very positive advances in utilization efficiency. Developments in natural gas technology such as high-efficiency equipment for industrial, commercial and residential use are helping to make natural gas even more efficient. For example, many new gas heating system designs began to enter the marketplace in the early '80s. Higher energy costs and an interest in conservation spurred new research and development by manufacturers, the gas industry, and research institutes to improve gas space heating equipment. Efficiencies were pushed from the old levels of 55%-70% to over 90% for some brands of home furnaces.

To achieve such impressive efficiency, manufacturers have employed advanced heat exchangers, forced draft combustion systems and more sophisticated controls to squeeze every bit of energy out of the fuel.

New high-efficiency high-temperature processes for the iron, steel, glass, pulp & paper, and food-processing industries are now available. These processes offer increased productivity and

improved quality control. Technologies currently being developed are also assuring that natural gas will remain an attractive option for modern high-temperature, automated heat treating processes.

For example, in the steel industry a new cokeless process melts scrap iron by using ceramic packing and natural gas burners in place of coke as a smelting medium. Besides being non-air polluting, the systems return high levels of quality control.

Conversions to natural gas can be made quickly, and they can pay off in a short time. As I mentioned earlier, natural gas can be selectively used with coal in thermal generating plants or in large boilers to significantly reduce emissions of sulphur dioxide and nitrous oxides. The cogeneration of electrical and thermal energy from natural gas is another highly efficient process which takes the waste heat from gas turbines to either produce more electricity or to be utilized in a process operation requiring heat. The applications are widespread: from industrial plants to hospitals, universities, shopping centres, department stores and office buildings. Since many of these facilities are situated in urban areas with high pollution levels, this use of natural gas increases efficiency and directly helps to reduce harmful emissions.

The United States has already installed cogeneration capacity large enough to account for five percent of its total electrical generation. Natural gas fuels almost half of these plants. Although not yet as prevalent in Canada, cogeneration is receiving

increasing attention and promotion from provincial governments and regulators.

*** Slide: Natural Gas -- Economical, Efficient, Versatile**

To summarize, then, the use of natural gas with or in place of other fuels provides reduced environmental impact in two ways:

- 1) When energy is supplied in the form of natural gas, the pollutant release per unit of energy is less than that of other fuels.
- 2) And secondly, the overall natural gas process is frequently more efficient, meaning that total energy use is cut.

As policy-makers weigh the facts on fuels, the role of natural gas in Canada's energy policy is assuming greater importance. Natural gas is a plentiful, economical, efficient and versatile fuel. But what's more important, given current environmental concerns, is that natural gas is the cleanest fossil fuel.

Legislators and energy consumers are becoming increasingly aware of the benefits of using natural gas. An excellent example of this is a recent energy policy unveiled by the government of New Brunswick. Although that province does not currently have access to natural gas, a significant portion of the policy paper focuses on its environmental attributes and desirability.

We're convinced that improved gas technology and the expanded use

of natural gas as a fuel for your industries, homes and vehicles can help improve the environment. Overcoming Canada (and the world's) environmental problems is a complex and vital task which will be high on the national agenda throughout this decade and beyond. The Canadian natural gas industry expects to make an increasingly important contribution to meeting this challenge.

Natural gas can help secure Canada's energy and environmental future.

* Title Slide: Natural Gas and the Environment

"Indoor Air Quality: A Poorly documented problem."

HANI BAZERGHII

Abstract

The subject is the lack of research on indoor air quality, the slowness of legislators, and the lack of documentation available to building managers and owners.

INTRODUCING...

Hani A Bazerghi, PhD, Engineering

A graduate of McGill (BSc, 1975), the École Polytechnique de Montréal (MAsc, 1977) and MIT (PhD, 1982), Hani Bazerghi is an associate of CMA Chalifour, Marcotte et Associés Inc. The firm's primary objective is to provide building managers with all the technical services necessary for the operation of their buildings, including consulting services on indoor air quality. Hani Bazerghi has already provided such services more than 25 times. He is also a member of the AQME's (Association Québécoise pour la Maîtrise de l'Énergie) Committee on Indoor Air Quality. It was for the Association that he wrote the "Guide Pratique d'Entretien Pour une Bonne Qualité de l'Air Intérieur", which is designed for building operators. The talk he will be giving today was prepared by his colleague Pierre Marcotte, who had to leave on a business trip.

TITLE: AIR QUALITY

A POORLY DOCUMENTED PROBLEM

Prepared by: Pierre Marcotte

Presented by: Hani Baserghi

1. INTRODUCTION

Are indoor air quality problems taken seriously in Quebec?

No, not really.

Despite extensive newspaper coverage of the problem;

Despite the number of "sick" buildings;

Despite the number of ventilation systems that operate under pitiful conditions;

Despite the growing number of building occupants complaining about various ailments;

Despite the waste of time caused by these problems;

Despite lost productivity;

Despite the waste of energy;

Despite all this

- there are few scientists who are concerned enough about the problem to prevent or correct it;
- there is little government action to improve controls;
- there is little documentation to help managers and operators improve air quality inside their buildings.

Despite the seriousness of the problem, few people are interested in it.

2. INVOLVEMENT OF THE SCIENTIFIC COMMUNITY

The scientific community has shown little interest in indoor air quality. Everyone has his or her own idea of what air quality should be. There are even a few scientists who call themselves specialists in this field. However, what are the facts when it comes to applying air quality standards to buildings?

Where can we find information about air quality discoveries?

Where can we find answers to air quality problems?

Certainly not in schools, because the subject is too new to have been incorporated into the curricula.

Technical journals, such as the ASHRAE Journal and its publications or other specialized journals, deal with the subject. However, these articles often only present a superficial treatment of the subject.

One has to attend international conferences and read the speakers' research papers to keep abreast of research and solutions to air quality problems.

The largest international conference on all the problems associated with indoor air quality is called "Indoor Air". In 1987, it was held in Berlin. Only three Quebecers and a total of 18 Canadians attended this conference. But Berlin is so far away, you say.

In 1990, "Indoor Air" was held in Toronto. Now, Toronto is not all that far away. So, how many Quebecers attended this first-rate conference, you wonder? A grand total of 56.

- 7 provincial government representatives
- 10 federal government representatives
- 21 academics
- 0 union representatives
- 18 private sector representatives.

There were more representatives from Denmark, Sweden and Finland than from Quebec.

But, you say, there are other international conferences where one can keep abreast of developments.

Climate 2000, Sarajevo '89:	only 5 Quebecers
Indoor Air Quality and Ventilation, Lisbon '90:	only 3 Quebecers

Because traditional building consultants have ignored this field of activity, academics are called upon whenever there is a problem. Academics can measure all kinds of pollutants and micro-organisms, which makes for big headlines in the newspapers. However, they have problems trying to translate the results of their measurements into concrete action in the construction industry. Sometimes, their recommendations are quite wild because they do not know anything about electromechanical systems in buildings.

This situation has to be reversed, however. Architects have to design buildings in which the risk of contamination has been reduced. They must choose materials that are more conducive to a healthy indoor environment. They must devise systems that are easier to clean and maintain. They must provide operators with documentation and more complete training so that they can understand and manage their buildings better.

3. GOVERNMENT ATTEMPTS TO IMPROVE THE SITUATION

Most regulations that have force of law in Quebec with regard to comfort and indoor air quality are outlined in the provincial "Regulations Respecting the Quality of the Work Environment", 15. These regulations set out minimum conditions, but they lag behind in many areas. Let us now review the chief factors concerning the comfort and well-being of building occupants.

3.1 Outdoor air quantity

Without being too explicit, the Regulations recommend 2.4 litres per second per person for commercial and industrial laundries, offices and laboratories. Other places are not mentioned at all. For buildings erected after August 1, 1983, the Act Respecting the Conservation of Energy in Buildings applies. Strangely enough, this Act increases the quantity of outside air that must be brought in. It refers to the ASHRAE 62-81 standard that stipulates that for an office, the quantity of outside air must

be 10 litres per second per smoking occupant and 2.5 litres per second per non-smoking occupant.

Since then, research on air quality has resulted in the fresh air minimum being raised to 15 or 20 litres per second per occupant, depending on the type of room. ASHRAE replaced its 62-81 standard with 62-89.

Did the Regulations follow suit? No. A committee met a few times last year to amend the Regulations, but it encountered resistance and did not make any recommendations. No changes were therefore made.

In old buildings, the standard is 2.4 l/s per occupant; in newer buildings, it is a little higher.

The Regulations absolutely must be amended to reflect the latest research on comfort and air quality.

- All new buildings must meet the ASHRAE 62-89 standard.
- Existing buildings should have two years to comply with the new regulations. Humidification systems should be added, and the capacity of heating and cooling coils should be increased in some instances, but not necessarily.
- The new regulations should take infiltration into account.
- Innovations could be made in the regulations by stipulating upper CO₂ limits to take into account the air in the systems and infiltration at each work station.

3.2 Relative humidity

With regard to relative humidity, the Regulations indicate that relative humidity must be kept at a minimum of 20%. However, these Regulations apply only to buildings erected after December

19, 1979. Even though 20% relative humidity satisfies a large segment of the population, a slightly higher relative humidity would result in even more satisfied people.

The Regulations absolutely must be amended to include the following factors:

- As a first step, the relative humidity level could be raised from 20 to 25% for all new buildings.
- Existing buildings should be given two years to comply with the new regulations. It is inconceivable that some offices can operate at less than 10% relative humidity.
- The Regulations should clearly state at which level this relative humidity should be maintained. Some people interpret the Regulations and maintain that relative humidity in garages should be kept at 20%.

3.3 Air speed

Another variable that affects comfort is air speed on the occupants' skin. Not enough speed makes the air seem stagnant, and excessive air speed means constant drafts. The Regulations Respecting the Quality of the Work Environment do not refer to this specifically. Rather, they indicate the total ventilation area of the system per person, which translates into a certain speed through space. However, there are no limits for each work station.

Partitions are often the culprit behind air stagnation in offices. Even though air circulates well above the partitions, there is little air movement inside the partitioned space. The Regulations should include a provision for air speed. They should specify

- the minimum and maximum air speed on the skin for each work station.

3.4 Volatile organic matter

The Regulations do not recognize volatile organic matter as a group of elements that are given off by furniture, paint and carpets. They therefore do not prescribe a maximum allowable amount for these volatile organic particles that affect large numbers of the population, especially in new buildings. They do prescribe a maximum for each component as if it were separate. We are however becoming increasingly aware that irritation is the result of the synergic effect of several components, each of which is present in very small concentrations. All of these components together are much more irritating than when taken individually.

The Regulations should include:

- maximum emission levels of volatile organic matter of the chief building material and furniture components;
- the maximum concentration of volatile organic matter at each work station.

3.6 Filtration efficiency

The Regulations completely ignore filtration efficiency. They do not go beyond specifying the maximum concentration of dust in the air. The City of Montreal's regulations on ventilation in buildings (By-Law 4936) are explicit in this regard; they set minimum efficiency standards for filters depending on use. Unfortunately, these regulations are not complied with because we know of at least one prestigious building erected in Montreal just a few years ago with filters that perform well below standards.

The Regulations should include:

- efficiency standards for filters for each type of space;

- minimum frequency for changing filters. As things stand now, filters can be kept in place for up to five years.

Twenty minutes is not enough to talk about all the aspects that should be dealt with in new regulations. However, we are convinced that the five mentioned above should be included.

4. ROLE OF MANAGERS AND OPERATORS

Building managers and operators are often blamed when there is a problem with air quality in a building. They are accused of managing their buildings poorly and of endangering the health of thousands of workers. But, if the scientific community ignores this field and if lawmakers do not provide them with the correct parameters for ensuring the comfort and well-being of occupants, where can building managers and operators turn for information to prevent these problems?

It is certainly not out of personal interest that they endanger the occupants' well-being, because all managers and operators try to keep occupants' complaints to a minimum. It is often a question of not knowing the basic principles and the ways in which these problems arise. These managers and operators want to know and understand. Proof of this are the 1,800 participants at our training sessions on the subject and an equivalent number who have taken courses given by the AQME.

To inform managers and operators better
To ensure occupants' well-being and to protect their health
To promote air quality that is consistent from one building to the next

we recommend that managers and operators be certified under a recognized training program.

Stationary engineers have to be certified, electricians and plumbers have to be certified, most tradespeople have to be certified. This is not true however of building managers and operators.

Caratakers or other unqualified personnel are often left with the task of looking after electromechanical equipment in schools, apartment buildings and offices. They do what they can but, lacking knowledge, they do things they shouldn't.

We would never think of leaving our cars in the hands of a caretaker who knows nothing about auto mechanics. This is often what happens, however, in buildings where systems are much more complex and the consequences, more serious.

Such a certification program would include training sessions:

- on the concept of comfort;
- on the basic principles of ventilation, heating and cooling;
- on how to operate each electromechanical system;
- on how to maintain each element.

This program could be combined with certification of ventilation systems because these systems ensure the occupants' comfort and well-being in modern buildings. Boilers, cooling systems and even elevators are certified, so why not ventilation systems?

8. CONCLUSION

Indoor air quality problems are here to stay. We can no longer bury our heads in the sand and think that the next energy crisis will solve our problems. The only way to solve them is through concerted action by governments, scientists, managers and operators. Such action must start by educating people about the phenomena that are involved.

A.C. SKIP HAYDEN

Notes biographiques

A.C. Skip Hayden a travaillé cinq ans dans l'industrie aérospatiale, a effectué de la R&D sur des méthodes de densité spectrale d'énergie pour l'analyse dynamique de systèmes linéaires et non linéaires soumis à des excitations aléatoires.

Depuis 1971, il travaille essentiellement au Laboratoire de recherche sur la combustion et la carbonisation (LRCC) de CANMET, EMR, et y effectue de la recherche et du développement sur l'efficacité des combustibles et la réduction des émissions. Il a touché à tous les types de combustibles solides, liquides et gazeux dans des applications qui vont des systèmes de chauffage résidentiels aux chaudières de service en passant par les automobiles sous climat canadien et les processus industriels.

Il est à l'heure actuelle chef de la Section de la technologie de la conservation de l'énergie du LRCC; il se concentre sur le développement et l'intégration de diverses techniques visant à augmenter l'efficacité de l'utilisation des combustibles et à aider à atténuer le problème du réchauffement du globe et autres problèmes environnementaux.

Il est l'auteur de plus de 100 publications techniques liées à l'utilisation des combustibles et est membre de quelque 20 comités nationaux et internationaux sur les techniques et les normes. Il est à l'heure actuelle directeur de la Division des sources de l'Association pour l'assainissement de l'air.

Il est marié et père de trois enfants.

Biographical notes

Worked five years in the aerospace industry, carrying out R&D on power spectral density methods for dynamic analysis of linear and non-linear systems under random excitation.

Since 1971, he has been primarily with Combustion Research Laboratory (CCRL), CANMET, EMR, carrying out research and development on fuel efficiency and emissions reduction. His R&D activities have covered all manner of solid, liquid and gaseous fuels in applications from residential heating systems, to automobiles under Canadian conditions, to industrial processes, right up to utility boilers.

Presently, he is Head of Energy Conservation Technology Section of CCRL, concentrating on developing and integrating various techniques and technologies to increase fuel utilization efficiency and to help mitigate the global warming problem and other environmental concerns.

He is author of more than 100 technical publication relating to fuel utilization and is a member of some 20 national and international technical and standards committees. He is also presently Director of the Source Division of the Air & Waste Management Association.

He is married, with three children.

**EFFICIENT COMBUSTION TECHNOLOGIES FOR HEATING:
REDUCING ENERGY USE AND POLLUTANT EMISSIONS**

A.C.S. Hayden
CCRL/ERL/CANMET

ABSTRACT

There is potential for significant reductions of 20-47% in energy consumption and pollutant emissions, including CO₂, by improving in the efficiency of fossil fuel-fired residential heating systems. This potential is scarcely realized to date in many areas. This paper discusses the efficiency potential of space and water heating systems fired by gas and oil, based on detailed experiments carried out by CCRL staff, both in the laboratory and in lived-in instrumented homes. Retrofit technologies will be discussed which change or modify existing stock, opening up the potential for major CO₂ reductions in the near term. Advanced, clean burning, wood combustion technology for residential space heating, coupled to properly managed wood harvesting, offers a means of utilizing a renewable energy resource, so that there may be no net CO₂ emissions.

EFFICIENT COMBUSTION TECHNOLOGIES FOR HEATING: REDUCING ENERGY USE AND POLLUTANT EMISSIONS

A.C.S. Hayden

Combustion and Carbonization Research Laboratory (CCRL)

ERL/CANMET/EMR

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INTRODUCTION

There is potential for significant reductions in energy consumption and pollutant emissions, including CO₂, by improving in the efficiency of residential heating systems. This potential is scarcely realized to date in many areas. This paper discusses the efficiency potential of space and water heating systems fired by gas, oil and wood, based on detailed experiments carried out by CCRL staff, both in the laboratory and in lived-in instrumented homes. With the latter, the effects on the whole house as a system were examined, considered and understood. The discussion applies equally well to equipment installed in poorly insulated older houses and also in new, well-insulated houses.

In the residential and commercial sectors, which account for 20% of Canada's carbon dioxide (CO₂) emissions, (nearly all of which is for space and water heating), major CO₂ reductions of 20-47% can be realized by modification or replacement of space and water heating equipment in existing dwellings/buildings and the development of new systems.

Closed-cycle biomass (wood) systems, coupling properly managed wood harvesting with advanced, clean burning, wood combustion technology for residential space and district heating, offer a means of utilizing a renewable energy resource, so that there may be no net CO₂ emissions.

If we are serious about making major CO₂ reductions over the next decade, the only way this can be realized is to have a program which changes or modifies existing stock/practice. New equipment, which should be regulated so as to only allow high efficiency appliances, will be coming on line too slowly to have a significant impact through the decade. Furthermore, the fact that the new structures will consume less energy by virtue of their original design has been factored into most projections for future CO₂ levels; on the other hand, little consideration has been given to the possibility of retrofit of the existing stock, where the major CO₂ reductions can be made.

As the emissions originate from the combustion of fossil fuels for space and water heating, any reduction in consumption by improved efficiency of these systems will translate directly into lowered CO₂ emissions of at least the same magnitude. That the potential exists to improve the efficiency of the heating systems by 20% to 47% shows that this is probably the most effective area to achieve certain major CO₂ reductions by a concentrated effort on specific equipment and infrastructure, without the significant dollar expenditure required in many other areas.

An additional benefit is that operating cost savings due to the increased efficiency will accrue to the consumer, giving him an economic incentive in this direction; however it is unlikely he will act unless other factors are employed, as well, as presented in this paper.

In order to appreciate the effects of various strategies to improve the efficiency of heating systems, it is worthwhile to examine the prime factors which affect the performance of the system over the entire heating season, as follows.

FACTORS AFFECTING FURNACE PERFORMANCE

There is a close relationship between the house and the heating system, with the relationship similar to the fundamental one of economics - demand and supply, as seen in Table I (1). On the left hand side are the Demand Factors - the reasons why heat is required; on the right hand side are the Supply Factors - the ability of the heating system to supply the heat.

Demand is controlled by the inside temperature requirement (the thermostat) and the colder outside temperature. At the same time, the house is constantly losing heat through two basic mechanisms, **Transmission Losses** and **Ventilation Losses**.

Transmission Losses are losses through the fabric of the structure. **Ventilation Losses** are due to the passage of air through holes in the structure. The common ventilation loss is the infiltration/exfiltration through cracks (around doors, windows, sillplates, etc.). A second component is directly attributable to a vented fuel burning heating system. When the heating system is off, there is a large direct opening to the outside via the chimney, through which warm air from the house and the furnace heat exchanger can escape or cold, outside air can enter the house.

The **Supply or Performance Factors** measure how well the heating system can supply the heat required. Three aspects must be considered:

- (1) **steady state efficiency** - the measurement with which the service industry is most familiar. It is commonly determined by stack temperature and excess air (as obtained by CO₂ or O₂ in the flue gas), once the furnace has reached equilibrium (steady state). However, it takes furnaces 4 to 14 minutes to get to steady state from the time that the thermostat calls for heat and the burner begins firing. Until then the furnace is in the ...

- (2) **transient state.** In general, most physical systems work much more efficiently in steady state. Just imagine your car. You use much more gasoline per kilometre accelerating and decelerating around town than you do cruising on the highway. Similarly, a furnace is generally much more efficient at steady state than in the transient condition.
- (3) **dilution air** through the draft dilution device (barometric damper on oil; draft hood or draft diverter on gas) accounts for a much larger air requirement and heat loss than does the air actually required for combustion - anywhere from 2 to 10 times the latter. The main purpose of this device is to isolate the burner from outside pressure fluctuations. New technologies such as induced draft fans, pulse combustion or high pressure drop burners eliminate the need for air dilution and the losses and problems entailed therein.
- (4) **combustion efficiency** measures the degree to which the fuel is completely burned. For oil- or gas-fired systems it is usually greater than 99.6%.

The combination of all these Performance Factors work together to give what is called the Seasonal Efficiency or Annual Fuel Utilization Efficiency (AFUE), a measure of how efficiently the energy in the fuel is actually supplied to the house over the entire heating season.

Figure 1 shows the effects of both the transient heat exchange and dilution for a furnace in a real house. The top two curves are for temperature and carbon dioxide (CO₂ - a measure of the excess air requirement) before the dilution device, and the bottom two are for the same two parameters after dilution. 8% CO₂ represents 100% excess air, while 1.7% CO₂ represents about 800% excess air, a dramatic difference. Consider that, for a typical house, 100% excess air represents a loss of heated air of about 2.5% of the total home heating load; 800% represents a heat loss of about 12%.

Figure 2 presents consumptions over time for two similar-sized houses with nominally-comparable insulation levels, but with house A built with superior workmanship by the owner, having almost half the other's consumption. Both consumption rates follow outside temperature variations closely, effectively linearly. Expressed in another way, consumption generally has a direct linear relationship, increasing with increasing degree days (decreasing outside temperature).

ENERGY CONSERVATION STRATEGIES

Thermostat Cutback

Thermostat cutback is an effective way of lowering heat demand, moving the linearly varying consumption curve (straight line) parallel to the right, giving less energy

consumption for any specific outside temperature (or inside temperature differential). This has the similar result to that of lowering the heat demand of the house by weatherstripping and insulating. Typically, a 1C cutback overnight will save 2% on the heating bill.

Improved Furnace Performance

Just as for reduced demand, improving furnace efficiency moves the consumption curve parallel to right, giving less consumption for any specific temperature differential. This can be achieved by reducing one or more of the losses described previously, improving burner performance, increasing the amount of heat exchange, eliminating the off-cycle heat loss, and/or reducing the amount of dilution air.

Reduced Firing Rate

For a conventional furnace, lowering firing rate to make the furnace more in tune with home heat demands makes little effect at mild temperatures but has an increasing effect on fuel efficiency as the temperature gets colder, so that the consumption profiles diverge and savings increase with decreasing outside temperature (2). Care must be taken not to reduce the firing rate too far, or the potential savings will be negated by the increased excess air required for proper combustion.

Chimney (Vent) Damper

A chimney (vent) damper closes off the flue when the furnace is not operating. It is located downstream of the final heat exchanger and draft dilution device. Contrary to the effect of reduced firing rate, savings with vent damper are greatest when the climate is mild and decrease as it gets colder, where the consumption profiles converge. Savings are more likely to be realized for a boiler than for a warm air furnace, due to the larger amount of heat stored in the former. If the firing rate has been decreased and/or a high pressure drop burner or ID fan is used, savings potential is decreased. For a warm air furnace, running the circulating fan longer to remove more heat from the heat exchanger will also reduce its potential. Moreover, the effect of the damper is almost negated if a fossil fuel-fired water heater also uses the same chimney. One problem that can result from the use of a vent damper is due to the heavy mass of stagnant cold air in the chimney from the off-cycle. This can disrupt start-up combustion performance, resulting in significant amounts of flue gas spillage into the house at the beginning of each cycle. Another problem results from the cold inside chimney walls, resulting in flue gas condensation and chimney degradation.

OIL FURNACE ADVANCES

Many regions of Canada still rely on oil as the prime residential heating fuel. For these areas, CCRL has and is developing a number of systems which can reduce emissions and energy consumption significantly.

Flame Retention Head Burner

Oil furnaces with high efficiency flame retention head or other low excess air burners should be required, coupled with reduced firing rate. Typically, changing from a conventional, cast iron head burner to a flame retention head oil burner will increase seasonal efficiency and give fuel savings of 15-20% (3). Reductions in CO₂, SO₂ and NO_x are comparable.

Delayed Action Solenoid Valve

Most of the emissions of incomplete combustion products (CO, gaseous HC, soot) occur during start-up and shut-down of the oil burner. Emissions, sooting potential and draft problems can be reduced by over 50% with the installation of a delayed action solenoid valve on the burner.

Mid-Efficiency Furnace (Forced or Induced Draft)

The mid-efficiency furnace will effectively eliminate the barometric damper, with its large air requirement. It may have an induced draft (ID) fan, located downstream of the furnace proper, which pulls the gases from the furnace and propels them up the stack; an alternative is a very high pressure drop burner with a properly baffled furnace, allowing the burner to withstand any pressure fluctuations transmitted from the top of the stack. It can improve the seasonal oil furnace efficiency to nearly 90%, without condensing. Fuel savings and emissions reduction for this mid-efficiency furnace would be 25-30%, relative to a conventional furnace. Compared to a flame retention head-equipped furnaces, real fuel savings would be at least 10-15%.

Additional benefits are reduced reliance on natural draft, much lower total air requirements and a safety shutoff in the event of flue blockage or reversal. Knowing the exact quantity and temperature of flue gas to be delivered to the chimney base allows proper sizing of the chimney to ensure adequate capacity, with little danger of condensation in the system. Indeed, it is possible to eliminate the chimney altogether, exhausting the combustion gases out the side wall of the house.

Condensing Oil Furnace

A further, possibly less-desirable development is a condensing oil furnace, either new or retrofit. Number 2 oil contains a certain amount of hydrogen which, on combustion, forms water vapour, tying up about 6% of the energy in what is defined as the Hydrogen Loss, mainly in the form of latent heat.

A condensing furnace makes a conscious effort to recover some of the Hydrogen Loss described above, by condensing some of the water vapour from the flue gases in an

additional heat exchange section. This additional section, made out of stainless steel, or plastic with a water spray, lowers the furnace exhaust gases below their dewpoint, regaining the latent heat contained therein.

Some condensing oil systems use two vents, maintaining a conventional chimney, along with a plastic pipe out the side wall of the house, both open at the same time. With this type of system, there is a strong possibility of the flue gases bypassing the water spray condensing system and going straight up the chimney. The barometric damper is also retained, so that the additional dilution air increases the overall heat loss, while lowering the dewpoint even further, making it even harder to condense the flue gases.

In any case, with oil containing much less hydrogen, the potential for efficiency improvements by condensing the flue gas is much lower than for gas - the dewpoint is lower, so you have to work harder to condense less, as shown in Figure 3. Also, with much higher sulphur levels, the condensate is more corrosive, so that any condensing heat exchanger for oil must be even more corrosion resistant. The fact that oil combustion also produces a certain amount of soot, which can concentrate the acidic condensate as "acid smut" at certain points on the heat exchange surface, makes things even more difficult. This furnace is only 0-10% higher in terms of efficiency than the mid-efficiency type described previously. For all these reasons, an oil-fired condensing furnace is likely much less attractive than a gas-fired one (4).

Both the mid efficiency and condensing oil furnaces offer major efficiency advantages and pollutant reductions over conventional existing appliances, with the mid-efficiency furnace seen to be the best way to go at this point.

Improvements to Tankless Coil Water Heating

In the East, tap water heating is often done either by electricity or by tankless coil in an oil-fired hot water boiler. Replacing the existing space and water heating systems by an advanced design integrated space/water heating system could give fuel savings and CO₂ reductions of 31% for space heating and 47% for water heating. If the water was previously heated electrically, CO₂ reductions for the latter of as much as 73% (35% to 85%, plus the difference between oil and coal CO₂ of 24%) can be reached. A retrofit system, using the presently installed boiler, but adding an indirect water tank and microprocessor controls, will also be developed for this application; such a retrofit would yield almost the same savings, but at much less cost than a total system replacement.

The concept of using a similar system with warm air furnaces is also being pursued.

GAS FURNACE TECHNOLOGY

Conventional Gas Furnaces

Most conventional gas furnaces have a continuously running pilot light, that accounts for between 3% and 5% of the furnace's fuel consumption if left running all year. For low energy housing, such as in the R2000 housing program, the % loss would be even greater because of the lower furnace capacity. Intermittent ignition devices (IID) (eg. spark ignition), eliminate this energy loss.

Such furnaces also have naturally aspirating atmospheric burners, with no fan/blower to assist either in the fuel-air mixing, nor in the generation or maintenance of draft. There is a very low pressure drop through the unit and under certain conditions they may be subject to flow reversals, particularly if other equipment with large air demands, such as the fireplace, are also operating. These gas furnaces also have a continuously open draft hood with a large dilution air requirement. This is obviously a major loss of heated house air up the chimney, both when the furnace is running and when it is not.

Generally, conventional gas furnaces operate with a seasonal efficiency of about 60%.

Vent Damper-Equipped Furnace

This type of furnace has a damper in the flue exhaust, downstream of the furnace heat exchanger, and draft dilution device, which is driven by a signal from the thermostat. It closes the flue when the burner is not operating and opens before the burner ignites. The unit must have an IID. The unit still has a draft hood and a naturally aspirating burner. Fuel savings are generally from 3% to 9%, with the greatest potential savings for hot water boilers. This furnace loses even this potential effect on efficiency if a conventional gas-fired water heater is also connected to the same chimney, as the water heater keeps the chimney open, and losses from the water heater can actually be increased.

Induced Draft (ID) Fan Furnace (Mid Efficiency)

The induced draft fan furnace has a fan downstream of the furnace proper which pulls the gases from the furnace and propels them up the stack. There is a spark ignition and no draft hood. Downstream of the ID fan there is typically only a small opening (2 cm) so the unit also operates as if it had a vent damper on the off cycle. Fuel savings and emissions reductions of the induced draft fan furnace, relative to a conventional furnace, would be from 10% to 25%, depending on the furnace design. Most of this type of appliance design should yield savings closer to the high end, and seasonal efficiencies on the order of 80%. This furnace represents a conundrum. If its efficiency is too high (i.e. >83%), some condensation and corrosion in the flue system is likely to occur. At

this point, rather than attempting to gain one or two percent in efficiency, you should go all the way to a ...

Condensing Gas Furnace

Natural gas has a high hydrogen content which, on combustion, goes to water vapour, tying up a large amount of energy in the form of latent heat and making the flue gases much more moisture-laden than oil; hence the desirable requirement for a chimney liner to avoid condensation, damage and even ice bridging in masonry chimneys. In comparison to oil, natural gas has twice the hydrogen content, resulting in a "hydrogen loss" of about 12%. This accounts for the fact that conventional furnaces and boilers have a lower efficiency when fired with gas than with oil.

High efficiency gas furnaces have an extra stainless steel heat exchanger wherein the combustion products are partially condensed and the latent energy is recovered. Flue gas temperature is reduced dramatically. At the same time, there is spark ignition and no draft hood. Designs with conventional combustion use an induced draft fan, downstream of the condensing section, to exhaust the combustion products. Other designs use a pulsating combustion principle, where no ID fan is needed - the pulse exhausts the products. Depending on the particular combustion and heat exchange design, fuel savings and emissions reduction can be from 26% to 37%, relative to a conventional gas furnace.

Because the flue gas temperature is so low with any condensing furnace, no chimney is required. The flue gas is merely carried in a plastic pipe to a exhaust vent on the outside wall of the house.

Contrary to conventional furnaces, the shorter the cycle length of a condensing furnace, the more water is condensed, due to cold furnace walls, and the higher the efficiency. This type of furnace generally has a seasonal efficiency at or even higher than its steady state efficiency, with transient effects negligible (5).

Advanced Plastic Condensing Furnace

CCRL has been carrying out further R&D to develop new and retrofit condensing systems which will be cheaper and even more efficient, using new concepts and materials, such as plastics, as opposed to the high cost stainless steels presently being used in condensing appliances (6).

The result is a plastic condensing furnace, with recirculated flue gas to control the temperature of the incoming flue gas.

Condensing Boiler

Condensing gas-fired heating systems are now also available for homes heated with hot water. CCRL has carried out field trials in houses where conventional and high efficiency boilers/furnaces are flip-flopped on a weekly basis. This boiler uses the pulsating combustion principle, operating at low excess air with high rates of heat transfer. There is no continuous combustion nor ID fan, but rather a regular series of combustion pulses, ignited by a spark and yielding high rates of heat transfer at low excess air.

Some efficiency gains have been realized with the condensing boiler, but not as high as expected. This is because, at typical return water temperatures above 50C, there is no driving force for latent heat recovery. The cooler the return water temperature, the more water is condensed and the higher the efficiency (5). Greater efficiencies can be attained by using an indirect service water pre-heater in the return water line before the boiler. The boiler inlet water temperature is driven below the dewpoint of the flue gases, so that condensation can occur, with efficiencies greater than 90%.

Retrofit Condensing Gas Furnace

Even today, most new homes are still being built with an inefficient conventional gas furnace, either due to pricing disincentives on the part of the builders, or the naive belief on the part of the home buyer that when he buys what appears to be a fairly energy-efficient home, he also gets an efficient furnace. Hence, the existing stock of inefficient furnaces is very high, and is actually growing. Means must be found to ensure that only high and mid efficiency equipment is installed in the future, both in new housing and as replacements in existing homes, probably through minimum efficiency standards.

However, recognizing that the installed stock of conventional furnaces is high and quite new (most less than 10 years old), CCRL/ERL/CANMET, in conjunction with a Canadian furnace manufacturer, has developed a retrofit condensing furnace. This unit can be added to an existing conventional gas furnace to improve efficiency and reduce CO₂ emissions by 33%. It is approved for sale in both Canada and the United States. In order to realize its potential, means must be found to encourage its use.

Gas-Fired Water Heating

Most homes heated with gas also have a gas-fired water heater, with a seasonal efficiency of about 50%. Use of an advanced design, induced draft fan water heater could reduce CO₂ emissions by 10 to 29%. CANMET's instantaneous condensing water heater would yield 42% savings in fuel and CO₂.

COMBINED SPACE AND TAP WATER SYSTEMS - OIL OR GAS

Presently, fossil fuel-fired water heaters are very inefficient, typically at or below 50%. Even so, by far the majority of homes heated with gas also have gas water heaters. CCRL is working to develop efficient combined heating and service water systems. An integrated condensing gas system, as in CCRL's prototype unit (7), can result in heating savings of 33% and tap water savings of 45%, with like CO₂ reductions. A further interesting potential exists to combine CCRL's advanced plastic heat exchange furnace with additional tap water and heat-recovery ventilating capabilities, to yield one overall combined system which could supply all these needs for new housing in one. The overall capital cost would be lower, the need for multiple exhaust systems would be eliminated and the efficiencies of all forms of operation would be maximized, with minimum CO₂ emissions.

A similar strategy can be used on oil-fired systems, to get around the problem of minimum firing rate requirements. When the thermostat calls for heat, the furnace runs to supply heat to the house. When the thermostat demand is satisfied, the furnace, instead of shutting off, continues to run, but dumps the heat into the water storage tank instead, ensuring high efficiency. The next time the house needs heat the process is reversed, and the furnace does not need to work. As well if tap water is required it is merely drawn directly out of the storage tank. The system uses a mid-efficiency concept for the boiler, with low thermal mass and a very effective counterflow heat exchanger to transfer the heat back and forth from the storage tank to both the space and the service water heating requirements. The efficiency for both space and tap water heating can be over 85%.

On gas, the system is similar, but is even more efficient, as it uses the cold mains water as the driving mechanism to condense the flue gas. This system has efficiencies of over 90%, for both space and water heating.

HEAT DISTRIBUTION SYSTEMS

For both oil- and gas-fired heating systems, the heat distribution systems are generally not nearly as efficient as they could be; a large portion of the heat generated goes to heat areas of the dwelling where it is not needed. In many cases, this is the basement, an area that, in most existing homes has little or no insulation, so that the heat is almost immediately lost to the outside. The first steps to take are to tape duct joints and insulate warm air ducts or pipes. Beyond that, improving duct runs and off-takes would be recommended. By improving the distribution systems in up to half the homes in Canada, it is estimated that a further 15-20% reduction in fuel bills and CO₂ emissions could be achieved.

WOOD HEATING

Fireplaces

Fireplaces are between -5% and 5% efficient. In other words, they supply little if any energy to the house, particularly with cold outside temperatures. Devices such as glass doors, "heatilator" type heat exchangers and even outside air supply improve the efficiency marginally, at the very best only to the 20% level. One of the main reasons for the low efficiency of the fireplace is its massive air requirements, which can cause problems in tight housing, either new or existing. Fireplaces can also be a source of hazardous pollutants indoors, resulting in either long term problems or immediate catastrophic poisonings. As well, fireplaces are very high emitters of outdoor air pollutants in the form of suspended particulates. The use of artificial firelogs can lower emissions by 50-80%, while reducing the chance of indoor spillage of the combustion products as well (8).

Space Heating Wood Stoves

One way that wood can be a useful energy source is to use a well-designed airtight wood stove, properly located in a major living area and vented directly into its own inside chimney, or into the fireplace chimney if it has been fitted with a stainless steel liner.

The major difference between wood and other combustion systems is that there can be a significant degree of incomplete combustion products. In an airtight stove, air for combustion is controlled through small ports. Wood burns in a complex manner, with the incomplete combustion products coming off the wood remote from the location of the flame. In conventional airtight stoves, including those built even 2 or 3 years ago, a large amount of incomplete combustion products (carbon monoxide, hydrocarbons and creosote) escaped the burning process to be deposited in the chimney as creosote and/or to be emitted to the environment as serious air pollutants.

Advanced, Clean Burning, Wood Stoves

In order to ensure clean, efficient combustion in the firing range required, major changes to the combustion design of wood stoves are required. New stove designs are now being developed which give better combustion and have lower heat outputs, to give a much more useful range of operation. There are a number of new designs, employing advanced combustion techniques or catalysts to reduce the amount of incomplete combustion products.

Stoves now reaching the marketplace show an 80% reduction (9) in emissions of incomplete combustion products (CO, hydrocarbons, particulates), with a 10-20% gain in efficiency, relative to stoves of five years ago, as shown in Figure 3. Such appliances can be an effective complement to conventional heating systems in many regions of the country; they offer the potential to displace 60-70% of the fossil fuel used for central

heating in these regions, with a similar reduction in overall CO₂ emissions. They are also ideally suited for use in electrically heated homes, easily displacing 70% of the electricity used for space heating.

Closed-Cycle Wood and CO₂

Biomass (wood) is relatively high in carbon and apparently would produce higher CO₂ emissions when burned; however, if considered in the context of the total carbon cycle, with proper harvesting techniques, cutting only diseased or mature trees, combustion of wood as an energy source can actually reduce the build-up of CO₂ in the atmosphere, or at least be CO₂ neutral. CO₂ is constantly being released into the atmosphere when biomass decays, so that biomass burning only accelerates this release. Moreover, this release is exceeded by CO₂ fixation in young forests, where the rapid growth takes up much more CO₂ than do mature trees.

Hence, proper wood harvesting, coupled to efficient, clean burning, advanced wood combustion systems, can be an important means of helping to mitigate the CO₂-greenhouse problem, while saving fuel dollars.

APPLIANCE AIR REQUIREMENTS AND INDOOR AIR QUALITY

Combustion appliances can also be a serious source of air pollutants to the indoor environment, due to inadequate venting or incompatibility with the rest of the systems in the house. Table II presents a summary of the air requirements of the various residential combustion equipment discussed, in terms of the number of air changes per hour and actual air flow rates, for a typical Canadian house (10). For the purposes of this paper, the typical house was taken to be a bungalow with a full basement, having a total internal volume of 498 m³. The measure of air tightness of a house is most often given in terms of air changes per hour, the air change being the total volume of air present in the house. To get some appreciation of what the number means, 0.5 air changes/hour are considered necessary by many groups to ensure that there is no long term build-up of contaminants for indoor air pollution. Some of the new, tight homes require forced ventilation systems (air-to-air heat exchangers) to achieve this level.

Conventional furnaces/boilers are seen to have air demands on the same order as the half air change rate of many tight houses. As such, they offer potential problem sources for spillage of combustion products, or even flow reversals in adverse circumstances, unless steps are taken to alleviate the problem.

Even worse, the fireplace has a potential air demand nearly three times that of a moderately tight house. How can this inefficient appliance not be expected to interfere with the operation of other air-breathing equipment?

On the other hand the higher efficiency oil- and gas-fired appliances and small

"airtight" wood stoves have no significant air demand and thus mate well with the lower energy consuming, tighter houses of today and tomorrow.

HOW CAN THESE EFFICIENT TECHNOLOGIES BE IMPLEMENTED?

Table 3 summarizes the fuel savings and CO₂ reductions possible with the varying technologies applied to the residential sector.

A number of actions have to be taken in order for the large potential CO₂ reductions possible in the existing residential/commercial sector can be realized. The different pieces of equipment must be developed and put together in retrofit packages. The industry supplying the equipment and service must be well trained and shown the benefits, so they can aggressively market it. Manuals must be written to support them. The public must be made aware of the large benefits from this equipment, at the same time as industry is gearing up to supply it. Standards must be changed to allow and facilitate the use of the equipment and regulations developed to only allow the use of high efficiency equipment in new installations.

SUMMARY

As has been seen, the potential for major reductions in fuel consumption through research and development in residential heating system technology is high, with continuing efforts required to achieve the required goals.

Changes in burner/furnace technology offer still further reductions in fuel consumption by improving combustion performance, reducing off-cycle losses, eliminating the need for downstream infiltration of dilution air and increasing dramatically the steady state efficiency with more heat exchange surface. For oil, the most promising of these improvements is the mid-efficiency oil furnace, without dilution air. The low air demands of this design coupled with its powered exhaust capability promises to remove the oil-fired appliance from consideration as a source of indoor air pollutants. For gas, both the mid (ID) and high efficiency furnaces offer major advantages in terms of efficiency and safety. The retrofit condensing gas furnace allows a conventional gas furnace to effectively become a condensing system, with high efficiency, low air requirements and no need for a chimney.

In conclusion,

1. CCRL/CANMET energy conservation technologies have the potential to produce significant immediate reductions in pollutant emissions, including carbon dioxide, of 20-47% from residential and commercial oil- and gas-fired systems, by improvement in the efficiency of both existing and new residential space and water heating systems.
2. Closed-cycle biomass (wood) combustion, coupling properly managed wood harvesting with advanced, clean burning, wood combustion technology for residential space and district heating, offer a means of utilizing a renewable energy resource, so that there are no net CO₂ emissions.
3. CCRL/CANMET's expertise is available to industry and others in this and in many other combustion areas to achieve significant reductions in CO₂ emissions.

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Table I. Factors Affecting Furnace Performance.

Demand Factors (House)		Performance Factors (Heating System)
Heat Requirements	Heat Losses	
- Thermostat	- Transmission	- Steady State Efficiency
	- Infiltration	- Transient Operation
	- Downtime Losses	- Dilution Air
		- Combustion Efficiency

SEASONAL EFFICIENCY

TABLE II. Air Demands for Residential Combustion Appliances.

APPLIANCE	AIR REQUIREMENT			
	Combustion m ³ /h	Dilution m ³ /h	Total m ³ /h	AC/h
Conventional Oil	65	195	260	.52
Retention Head Oil	44	195	239	.48
High Efficiency Oil	37	-	37	.07
Conventional Gas	51	143	194	.39
ID Fan Gas	44	-	44	.09
Condensing Gas	29	-	29	.06
Fireplace	680	-	680	1.4
Airtight Wood Stove	17	-	17	.03

Table 3. Energy and CO₂ Savings for Different Residential Space and Water Heating Technologies

<u>FUEL</u>	<u>TECHNOLOGY</u>	<u>CO₂ & FUEL SAVING, %</u>
OIL	Advanced Burner	20
	Advanced furnace (mid-efficiency)	31
	Integrated space/tap water mid-efficiency system	31 space 43 water-oil 60 water-elect
GAS	Condensing furnace	37
	Mid-efficiency furnace	26
	Retrofit condensing furnace	33
	Mid-efficiency water heater	27
	Integrated space/tap water condensing system	33 space 47 water-gas 62 water-elect
OIL & GAS	Improved heat distribution	15-20
WOOD	Advanced combustion design	15/100

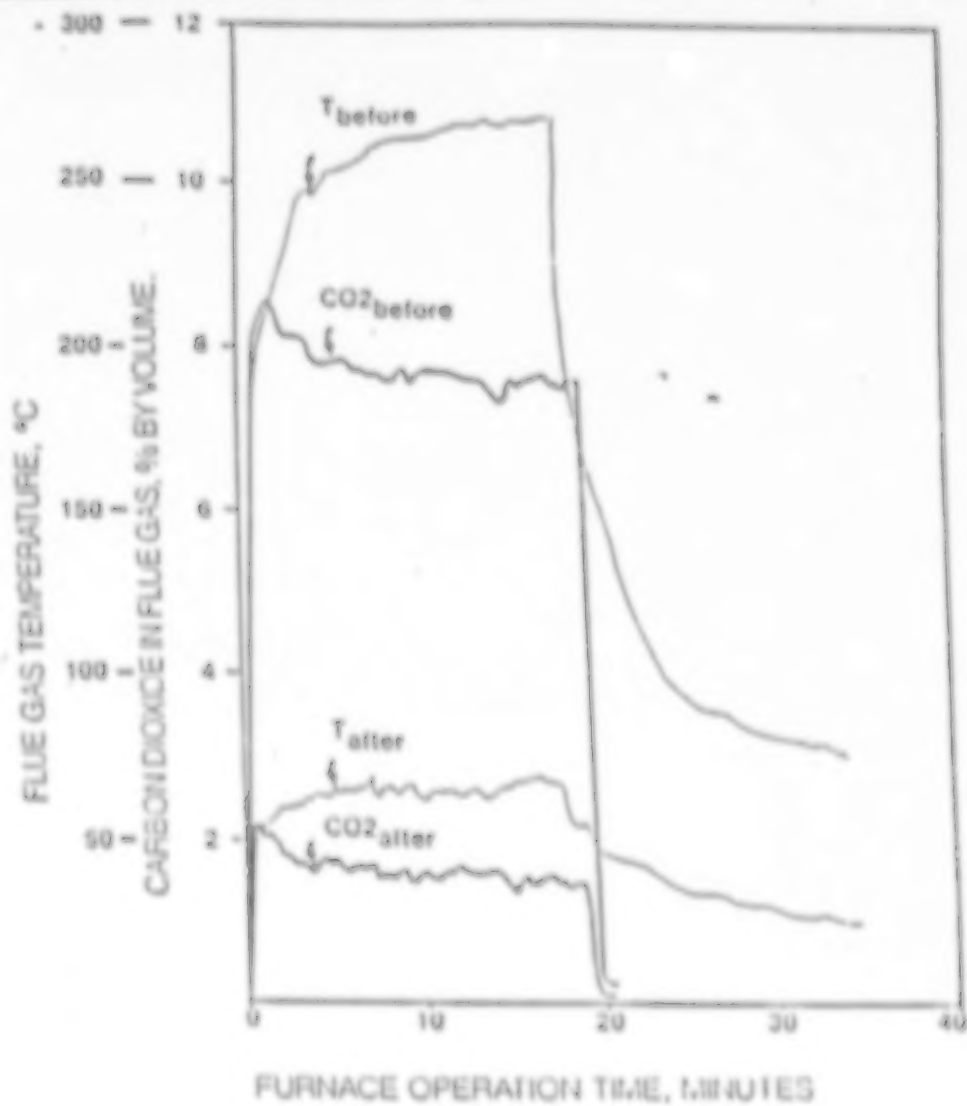


Figure 1. Effect of dilution on flue gas temperature and composition, House C.

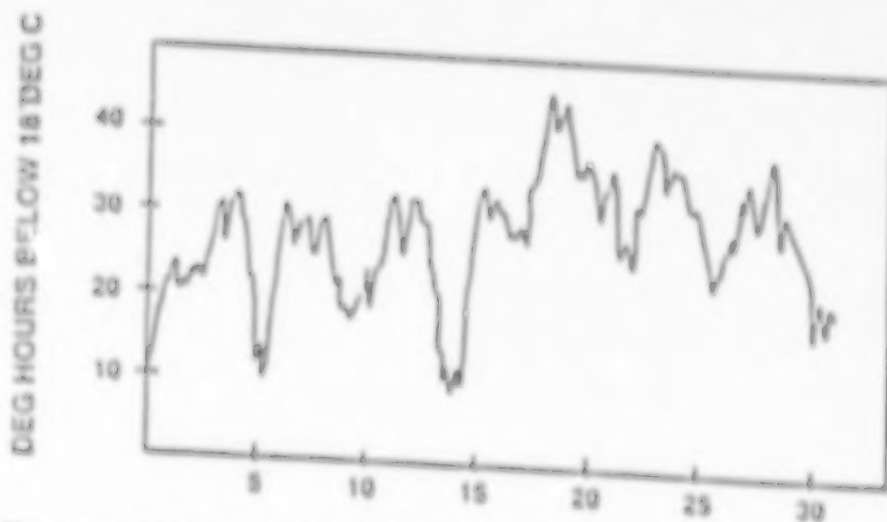
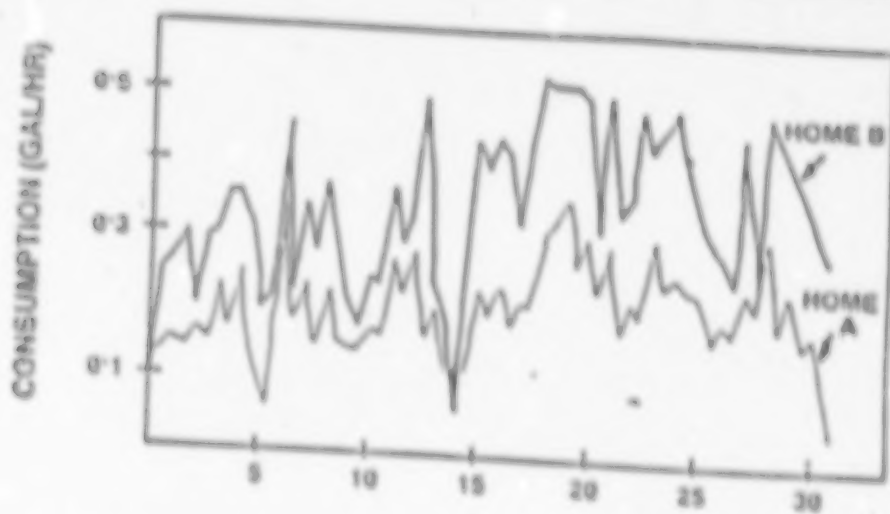
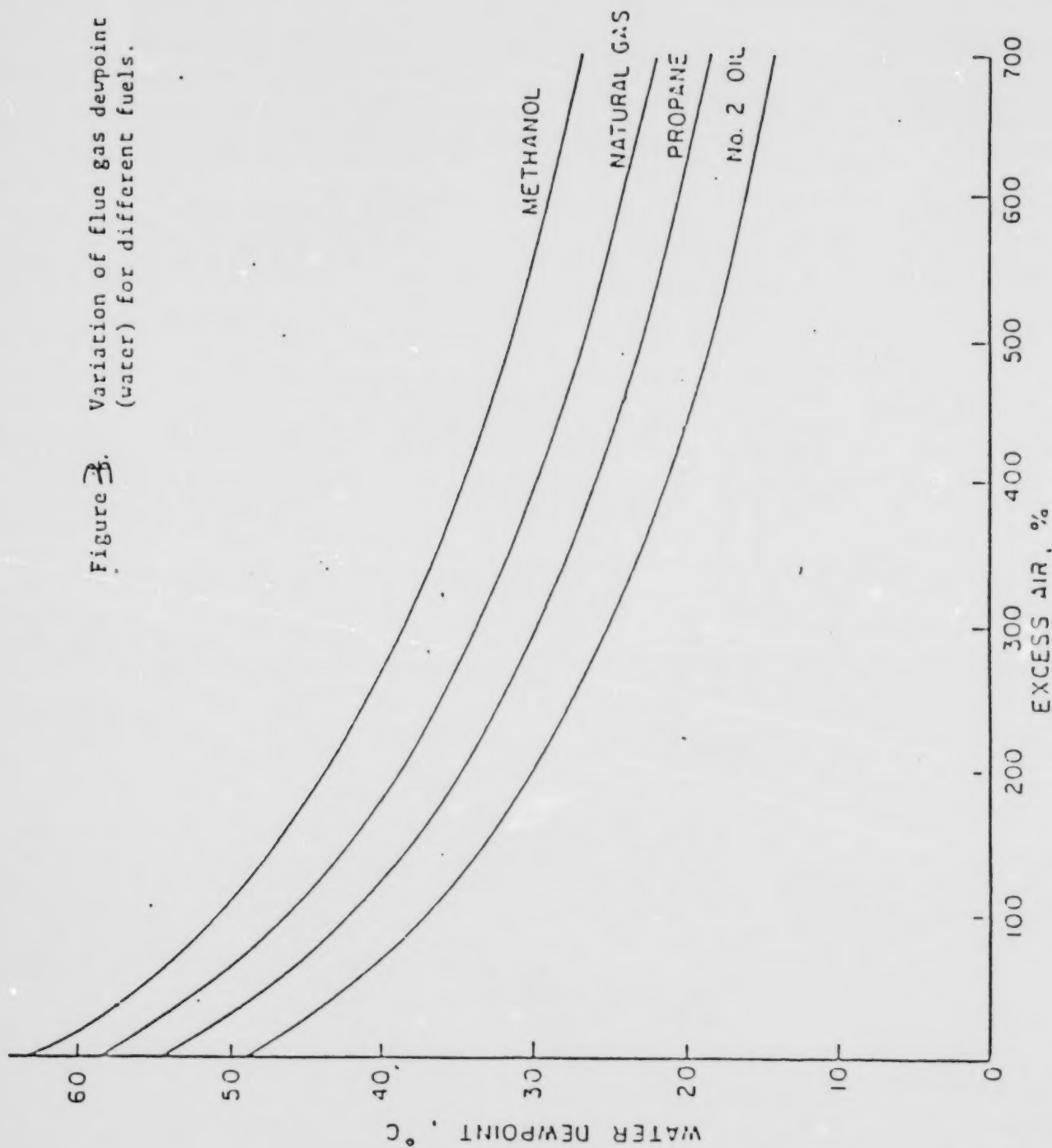


Figure 2. The effect of external temperature on fuel consumption Homes, A and B.

DECEMBER

Figure 3. Variation of flue gas dewpoint (water) for different fuels.



MICHAEL CONROY

DISTRICT MANAGER, CENTRAL MAINE POWER COMPANY

Michael Conroy is currently a District Manager for Central Maine Power Company. In this capacity he provides management for meter, line, and credit operations as well delivery of energy management services to customers within his region.

Mike joined Central Maine Power Company in 1979 as an Assistant Division Power Advisor. He has held positions of Division Power Advisor, Staff Engineer-Load Management, Division Customer Service Supervisor, and Director of Division Customer Services.

In these capacities Mike has provided engineering advice to customers regarding energy management within their facilities, has performed design and technical support for energy management programs, and has provided direction for the delivery of energy management services to many of the company's customers.

Mike is a registered professional engineer in the State of Maine. He holds a Bachelors degree in Electrical Engineering from Cornell University, and a Masters degree in Business Administration from the University of Southern Maine. He is a director of the Maine Association of Engineers.

Mike lives in Dover-Foxcroft, Maine with his wife Terri and their children Nicole, Nathan, and Sean.

Energy and The Environment Conference

March 20, 1991

Demand Side Management And The Environment

Michael H. Conroy
District Manager
Central Maine Power Company

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Demand Side Management And The Environment

CMP is continually working to assess and plan for our energy future. Events like the war in the Persian Gulf, concerns over acid rain and the "Greenhouse Effect" and increasing opposition to new generating and transmission facilities combine to give more importance to careful, flexible and diversified resource planning.

Our Company is committed to an Energy Resource Plan that meets the requirements of Maine Energy Policy and honors the preferences of the people it is intended to serve as fully as possible. Demand Side Management continues to be an important piece of that plan.

Michael H. Conroy
District Manager
Central Maine Power Company

Good Afternoon!

I appreciate the opportunity to join you at this conference. My Topic, Demand Side Management and the Environment is one that is important to Central Maine Power Company and to each of you as energy professionals. As the world's interest in the environment increases, so does the importance of demand side management.

As stated in our recent Energy Management Five Year Outlook, Central Maine Power has pursued for almost a decade the goal of developing energy management programs which are cost effective, environmentally benign and of value to our customers. In this effort we have not only succeeded but we have been among the nations leading utilities and our commitment to demand side management has not diminished. In fact, CMP's 1991 budget of over \$28 million is its highest ever-representing 4 percent of our gross sales revenue.

Today CMP experiences peak loads on the order of 1800 megawatts. We are a winter peaking utility. Our annual energy sales are approximately 9200 gigawatt hours to a mix of residential, commercial, and industrial customers.

Our capacity supply mix includes approximately 200 megawatts of energy management, 1500 megawatts of CMP-owned generation, 150 megawatts of Canadian purchases, and 500 megawatts of co-generation and small power purchases.

As our demand side management expenses grow, we become increasingly concerned that our investment in demand side management be made wisely. We want to do the best job possible of obtaining this resource at the lowest cost for our ratepayers while being responsive to public policy mandates.

For the past decade the public policy mandate for Central Maine Power Company with regards to demand side management has become increasingly clear.

In 1980, the Maine Public Utilities Commission instructed Central Maine Power to factor energy management into the calculations for meeting its resource needs.

In 1987 the MPUC required that energy management resources compete with supply side resources on equal terms in CMP's long range energy resource planning.

Through the Maine Energy Policy Act of 1988, the Maine Legislature committed Maine utilities to integrated least cost planning. They also required that resource needs be met first from demand side efforts, then from cogeneration purchases then from other purchases (such as from Canadian sources), whenever other considerations are equivalent.

To date demand side management programs have been implemented and continued if they were cost effective. The proper measure of cost effectiveness is now again a matter of debate.

A program is currently considered cost effective if the total cost per kilowatt or kilowatt-hour is less than our avoided cost. There is no consideration for revenue erosion and little emphasis on the impact of the programs on rates.

Today Central Maine Power Company is seeking to reopen public discussions on the economic impacts of Demand Side Management. A proposed amendment to the Maine Energy Policy Act, possible changes in the cost effectiveness test, and incentive rate making are all vehicles which could recalibrate the economic yardstick used to measure Demand Side Management programs. Even if no changes result from these proposals, CMP believes the public discussion of the complex issues surrounding Demand Side Management investments will reaffirm the interest of the legislature, regulators and our customers that CMP's investment of ratepayer dollars in this manner the preferred.

Unfortunately, this has led some to think CMP has weakened its commitment to Demand Side Management. This is not the case.

The Electric Power Research Institute recently claimed that demand side management efforts could be saving the American Electric industry three percent (3%) of its load by the year
1
2000.

Central Maine Power Company saved over 3 percent of its energy requirements in 1990 through the cumulative effort of its Demand Side Management efforts over the past several years. In other words, we are 10 years ahead of EPRI's projections for our industry.

Mr. David Moskovitz, former Maine Public Utilities Commissioner and now energy consultant, said last June, "To be sure, investing heavily in energy efficiency is the best thing we can do for the environment. In this respect, Central Maine Power Company leads the nation."

Central Maine Power Company spent approximately \$71 million on demand side management from 1982 through 1990. We have budgeted over \$28 million for 1991. We are aware of only one utility in the nation that spends a higher percentage of its revenues on demand side management - New England Electric System. However, they have incentive rate making which removes the usual disincentive to sell less of your product and in fact provides a financial incentive to save. Central Maine Power Company spends more of its revenue than any utility that does not have incentive rate making.

As stewards of the environmental, human, and financial resources entrusted to us, we must ensure that these dollars are invested wisely.

The last few years at Central Maine Power Company we have refined our planning models, program design, evaluation, and marketing abilities to more accurately determine the most effective mix of energy resources for the CMP system.

In 1990 CMP added significantly to the Demand Side Management component of our resource mix. Through 24 programs we achieved annualized savings of 148 million kilowatt hours. We reduced our coincident peak by 33 megawatts and completed almost 43,000 customer energy efficiency projects.

Perhaps our greatest success in 1990 was a timely campaign titled "Insulating Downeast From The Middle East". In this campaign Central Maine Power Company offered free installation of water heater jackets from mid-September through December 31st.

Our print ads featured Central Maine Power Company's reduced dependence on oil to generate electricity from 57% in 1970 to 20% in 1990.

The promotion resulted in 12,000 additional wraps and a 630% increase in calls to our toll-free energy management number. This brings our seven year total to 130,000 water heater jackets.

The Marketing Department achieved 236 percent of its goal for Insulation Plus and low-income energy-management program

installations in 1990. These are the programs through which we provide insulation and weatherization services.

Lighting rebates made in retrofit and new construction programs exceeded their 1990 goals by more than 300 and 200 percent, respectively, and the Company completed its municipal street light conversion program, assisting communities in reducing their electric usage. More than 90 percent of the street lights in CMP's service area are now energy efficient.

Industrial customers also are continuing to save energy through the Power Partners and Efficiency Buy Back programs. CMP has signed contracts with SESCO, Northeast Energy Management Inc., Puget and Keyes Fibre under Power Partners. Among the customers saving energy through Efficiency Buy-Back is Sugerloaf USA, which installed new snowmaking equipment.

Our successes haven't happened over night nor have they happened entirely through planning and having all of the right answers in advance. In 1983 our budget for Conservation and Load Management was only \$180,000. Our information for planning and our ability to deliver energy management services were not nearly as developed as they are today.

Numerous reasons could be cited for our successes since that time. I would like to highlight three today. First is a bias for action. Second is a sensitivity to customer's needs and preferences. Third is pricing.

In the Mid 1980's we wanted to pursue savings in the Commercial/Industrial Market. We began slow by performing Energy Audits and gathering data. By 1986 it was important to move beyond the planning stage to implement programs. Lighting and Motor Rebate Programs were designed. They were established as pilot programs so that we could learn from our efforts before moving to full scale programs. We have continually offered programs to our Commercial and Industrial customers since that time, always checking our results, improving the programs, and continuing to act. In 1990 our efforts with Lighting Rebates alone resulted in annualized savings over 43 million kilowatt hours.

The second principal we follow is to focus on our customer's needs and preferences rather than on what is convenient or logical from our point of view. The success of any Demand Side Management program requires good technical estimates of potential. But it also requires finding ways to enlist customer cooperation to reach that potential.

A good example from Central Maine Power Company's experience was our water heater control program. Water heater control appeared to provide tremendous potential for managing peak demand by shifting load. Based on other utilities efforts, CMP designed a pilot program that included a \$2.00 monthly credit on the bills of people participating in the first trials.

Customers who participated in focus groups identified several problems in our approach. Some feared running out of hot water. Others thought the \$2.00 credit was an insult. Still others disliked the idea that the utility would be controlling their water heater. The more these customers learned about the program the less they liked it.

In response we modified the program to emphasize water heater "cycling" rather than "control." We limited the cycling to weekdays during the winter peak months and increased the payments. The revised customer-influenced program was received much better in the focus groups and in the real world.

In my opinion one of the most effective tools we have to encourage our customers to use energy efficiently is pricing. A moment ago I spoke of the \$2.00 monthly credit for water heater cycling. That was one aspect of pricing. The aspect I would like to emphasize right now is the pricing of our electricity itself.

Central Maine Power Company's rate schedules for electricity underwent major design changes in 1986. Our standard residential rate became an inverted block rate. That is, the more customers use the more they pay per kilowatt hour. Furthermore, all high use residential customers are required to take service under a Time-Of-Use rate in which the price per kilowatt hour varies by time of day and by season. For customers on these rates, the energy management programs become a more valuable opportunity for them to control their costs.

Between 1986 and 1988, all General Service customers with peak demands over 400 kilowatts were placed on Time-Of-Use Rates also. These rates feature price differentials for time of day, week and year. The demand charges in particular are significantly higher during the winter months of December through March than during the other eight non-winter months. The rates provide strong signals and incentives for customers to shift load or save energy. The energy management programs then provide the tools.

Having the signals given to customers through rates consistent with the goals of our energy management programs and messages in energy education has been a tremendous asset in our efforts to encourage efficient uses.

It is time to look ahead to our need for energy resources and where energy management can play a role.

Our outlook is that demand for electricity will grow at two (2) to two and a half (2 1/2) percent per year over the next ten years even though for the short term our growth has been reduced to approximately one percent per year.

We expect increased population base, growth in our economy and advances in conservation.

We fully expect growth to vary by market segment with the paper industry leading growth, commercial and industrial remaining strong, and small residential growth.

As we examine our supply outlook we see that CMP oil units are ageing. Six units will reach their design life by the year 2000. These six units represent 370 megawatts or 15% of today's capacity. They also represent a significant portion of our peaking capability.

Our New Brunswick contract expires in 1991. This contract represents 150 megawatts.

We have contractual arrangements to purchase 180 megawatts beginning by 1997, but we have 130 megawatts of existing contract capacity scheduled to expire by the year 2000.

In summary there is a significant need for energy sources. However, there is no urgency in the short-term and our key focus is five to fifteen years ahead.

Existing resource management affects this need. You will see on this chart our peak requirements offset by existing and committed resources followed by interruptable capability, a continuation of our energy management efforts, some potential for paper company generation, and extension of contracts with other qualifying facilities. We also have the possibility of revitalizing some of Central Maine Power Company's existing units such as life extension for our Wyman units 1, 2, & 3.

With the significant uncertainties facing us in economics, demographics, regulation, technology, and our markets, Central Maine Power Company hopes to maintain a portfolio of resource opportunities that provide both flexibility and diversity.

We also need to pursue changes that will create a more competitive market. One means of creating this market is incentive regulation. CMP believes it should receive comparable incentives whether it meets customer needs through energy management programs, non-utility purchases, or additions to its own generation resources. The company believes the public interest would be served best by balancing any provision for regulatory penalties with the prospect of incentives for above par performance.

Another means of creating a more competitive market is to price all energy or fuels at their total cost. Costs of externalities such as air and water emissions, noise, scenic degradation, wildlife impacts, and health effects would be considered in energy pricing. In general any citizen or organization involved in economic choice will tend to make better decisions from the stand point of social concern and economic efficiency when confronting full price signals on the cost of that choice.

In evaluating our resources options we look at several integrated planning criteria including cost, reliability, adequacy, environmental acceptability, financial integrity, diversity, and flexibility. It is important to recognize each of these criteria in establishing a least cost plan.

Taking maximum advantage of economic Demand Side Management resources at the lowest possible cost is critical. As environmental "externalities" are internalized, Demand Side Management's value and its attractiveness in a least cost plan will continue to grow.

In this field, CMP plans to continue in its leadership role, working actively with government and its ratepayers to establish a solid, low cost energy resource mix to serve our customers' future energy needs.

In closing I would like to share with you some comments made by our President and Chief Executive Officer Joe Collier at a conference last year. He said "Energy efficiency helps this country compete, helps extend the life of our resources, helps improve its air and water and land, helps give people more choices and more money for the other needs of life, and helps preserve the financial integrity of electric utilities."

"Energy efficiency isn't a fad, it's an imperative that comes from a broader view of resources and broader view of the costs of using them."

I hope this presentation and the others at this conference will help each of us in some way continue in our important work toward energy efficiency.

I thank Michel Lamanque and Energy, Mines and Resources of Canada for the invitation. I thank you for your attention and I wish you a very productive conference.

Biographical notes

JIGAR V. SHAH

Jigar Shah graduated with a PH.D. in Chemical Engineering from the University of Florida in 1978. He spent seven years in Exxon in diverse assignments relating to process engineering and engineering computing. As a consultant for the last five years he has carried out energy efficiency studies for Linhoff March in food and chemical industries. He has also been involved in several environmental projects in the coke oven industry. His current responsibility in Linhoff March as a Business Development Manager is to develop and manage key accounts.

"Pinch Technology: The integrated approach to industrial processes."

JIGAR V. SHAH

Paper abstract

The paper gives a brief introduction to pinch technology and describes the use of composite curves in assessing optimum heat recovery in manufacturing processes. Reasons for non-optimality are discussed. Examples are given of the applicability of the technology to a wide range of process industries.

Recent developments, including exergy analysis, debottlenecking and waste minimization are described and the paper concludes by looking to the future, in particular the use of pinch technology in addressing environmental issues.

**PINCH TECHNOLOGY; the integrated approach
to industrial processes**

**Jigar V. Shah
Business Development Manager
Linnhoff March Limited
United Kingdom**

Energy and the Environment Conference

**Sheraton Hotel
Montreal**

March 20th 1991

INTRODUCTION

The modern requirements for energy management, minimum capital cost for plant design and the reduction of plant emissions are placing what would appear to be conflicting demands upon the plant engineers. However, there is an established technology that can provide assistance. Pinch Technology, developed a few years ago as a tool for saving energy in existing plants during the last period of escalating oil prices, has now become an established tool for debottlenecking, yield improvement and capital cost reduction. More recently, it has been shown that Pinch Technology can also be used with regard to flue gas emissions, waste minimization and the evaluation of waste treatment options.

The technology has several key principles

- . setting thermodynamically rigorous targets for process utility consumption
- . identifying modifications to process operating conditions which can further reduce the targets
- . thermodynamically correct integration of unit operations such as evaporation and distillation
- . design optimal utility systems
- . systematic design of processes which meet the targets.

Pinch Technology first identifies sources of heat (termed hot streams) and sinks (termed cold streams) from the heat and material balance of a process. By combining hot streams in given temperature ranges, we can produce the 'composite curve' of all hot streams, the hot composite curve. A similar construction for cold streams in given temperature ranges produces the cold composite curve. If the composite curves are plotted on a common temperature-enthalpy axis, we can define the energy target for the process as shown in Figure 1. The relative position of the two curves and hence the energy target is fixed by the chosen minimum temperature driving force, DT_{min} . This minimum driving force will normally be observed at one point only between the hot and the cold composite, called the "pinch". The pinch point has a special significance.

To understand this significance, we divide the process at the pinch, as in Figure 2. Above the pinch (in temperature terms), the process is in heat balance with the minimum hot utility, Q_{Hmin} . Heat is received from hot utility and no heat is rejected. The process acts as a heat sink. Below the pinch (in temperature terms), the process is in heat balance with the minimum cold utility, Q_{Cmin} . No heat is received but heat is rejected to cold utility. The process acts as a heat source.

If we choose to transfer heat, say 'XP', from the system above the pinch to the system below, the pinch equation presents the result quantitatively:

$$A = T + XP$$

Actual Energy Consumption	Target	Cross Pinch Heat Flow
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In other words, to achieve the energy set by the composite curves, the designer must not transfer heat across the pinch in any form:

- (i) process to process
- (ii) use of cold utility above the pinch
- (iii) use of hot utility below the pinch

These rules, if observed in design are enough to ensure that the energy target is achieved in practice.

The composite curves show us the scope for energy recovery and the hot and cold utility targets. Generally, a number of different utilities at different temperature levels and of different cost are available to the designer. Another Pinch Technology tool, the grand composite curve, helps the designer select the best individual utility or utility mix. The grand composite curve presents the profile of the horizontal (enthalpy) separation between the composite curves with a built-in allowance of DT_{min} . As illustrated in Figure 3, its construction involves bringing the composite curves together vertically (to allow for DT_{min}) and then plotting the horizontal separation (X in Figure 3).

Figure 4 shows how the grand composite curve reveals where heat is to be transferred between utilities and process and where the process can satisfy its own heat demand.

Track Record

Linnhoff March is the world's leading consulting company for Pinch Technology founded in 1984 by Professor Bodo Linnhoff, the pioneer of the technology. In 7 years of operation we have undertaken over 300 assignments world-wide with the following breakdown across industry sectors:

	(%)
Oil Refining	15
Petrochemicals	20
Specialty Chemicals	15
Food and Beverage	25
Pulp and Paper	10
Other	15

This represents a remarkable spread of success of a technology which was initially regarded as only being appropriate to the large, continuous processes of the petrochemical industry. Indeed, some of the most successful results have been achieved in the specialist, batch processing sectors.

Our experience in Canada, starting with our first job with Shell in Calgary in 1985, has developed rapidly over the last few years, as indicated in Figure 5. We are grateful to Energy, Mines and Resources for the support they have given to the technology since 1988 by way of training seminars and project funding.

Recent Developments

On-going research and development in Pinch Technology is being carried out at the University of Manchester Institute of Science and Technology (UMIST) in England, under the direction of Professor Linnhoff. This work is funded by a consortium of 17 multi-national companies who are committed to the technology (Figure 6). These seventeen companies have early access to the results of the latest developments at UMIST and meet annually to compare and discuss their recent applications and successes.

Figure 7 shows the progressive developments in the technology, since the basic concepts were established in 1978. The most important areas of development today are in exergy analysis, debottlenecking of batch operations and systematic approaches to waste minimization. Because of the important commercial implications, all these aspects are being developed in-house by Linnhoff March in addition to the work at the University.

In terms of process development, Pinch Technology has identified significant improvements in the design of nitric acid plants and of breweries, for example. This has led to the granting of a patent for the former and the development of a licensed package for the latter, called Brewery 2000. The owners of the brewery design package are Linnhoff March, Energy, Mines & Resources and British Gas - a truly international project.

Environmental Issues

In general, process operators have three broad categories of action to take when facing emission issues. They can modify the process design to reduce emissions, they can improve operations to reduce emissions or they can install appropriate emissions treatment facilities. In any situation, the number of potential solutions that could be identified is very large, and each solution will have different capital and operating cost implications. The issue for the operator is complex - 'how do I make sure that I am taking the best course of action?' Clearly, a structured approach to assessing the options is desirable. This paper outlines such an approach.

The key features of the methodology are:

- . developing an understanding of current operations from both a design and operations perspective
- . identifying design improvements to minimize waste

- . identifying operations improvements to minimize waste
- . identifying the best integrated effluent treatment options.

The last point is an important one. In many instances, competing treatment options are evaluated on a stand alone basis. By doing this, many opportunities for reducing the capital and operating costs of treatment facilities are overlooked.

There are several design and analysis techniques available to assist the operator in implementing the methodology; process modelling and simulation, process integration based on pinch technology, and monitoring and targeting. Each has a different role in the design and operation audits which are central to the methodology. Process modelling and simulation provide a means of determining how the process should be operating and understanding how operating variables can affect waste production. Process integration techniques provide a structured approach to identifying process improvements involving selection and operating of unit operations and overall integration opportunities which reduce capital and/or energy costs for the 'total' process. Monitoring and targeting provides a means for assessing the existing operation, identifying no cost or low cost operational improvements and confirming the success of effluent reduction projects.

The heat and material balances are the fundamental relationships which govern process operations (Figure 8). The material balance provides the relationship between raw materials, products and waste. Clearly, it is important to know what the relationship is before attempting to reduce waste production or utilize waste treatment. The heat balance provides information about the utilities required to make the process operate. The two are closely related, and understanding the relationship provides valuable insight as to how the process should operate and ultimately as to how the process can be changed to reduce environmental impact.

A good process model provides the basis against which to compare existing operations. It helps to identify problems and quantify the benefits of correction. For example, a model was developed for the simple cooking operation shown in Figure 9. It indicated that 0.8 kg of water was required for every kg of product. However, actual recorded consumption was 0.95 kg of water per kg of product, 19% more than required. With this information, it was found that the make-up control was not working correctly and causing the tank to overflow. This resulted in excess consumption of water and steam and excess flow to sewer. Without knowing what the material balance should be, this type of problem cannot be identified. A model provides a sound basis against which to compare existing operation to identify operational improvements or to assess potential process changes.

Waste Minimization

In general, the best way to deal with effluent production is to minimize waste production at source. In many instances, this will involve separation of one or more components from an aqueous stream. The options for separation include evaporation, distillation, crystallization and so on, all unit operations which involve addition or removal of heat. The decision to implement a waste minimization project may include costs for capital, energy, waste disposal and raw material recovery. This is a situation which is ideally addressed by Pinch Technology.

Consider a soft drink manufacturing process which results in production of a large volume of waste water. The disposal cost of this was significant enough that purchase of an evaporator to reduce the volume was planned. The evaporator chosen was a mechanical vapour compression unit which is a very efficient stand-alone unit. The initial cost is, however, relatively high because of the compressor required, and the low temperature driving forces in the unit. Figure 10 shows the existing and proposed processes. The project is attractive but one of the primary lessons of Pinch Technology is that individual unit operations should not be considered in isolation. By drawing boundaries around unit operations, many potential benefits of integration can be lost. The pinch techniques described earlier can be used to identify better options.

Using Pinch Technology, we would first start by generating the grand composite curve for the basic process. This is shown in Figure 11 and indicates that the process has a requirement for a considerable amount of low temperature heat. This demand is currently satisfied by 5 bar steam from the site steam system.

An evaporation process is driven by a high temperature heat input and results in heat being rejected at a lower temperature. Conventionally, the number of evaporator effects to use is based upon a capital-energy trade-off for the evaporation system. But what happens when the evaporation is integrated with the rest of the process? Figure 11 also shows how the heat rejection profile of the evaporator can be matched to that of the process. In this case, a double effect evaporator can be used to accomplish the necessary concentration at no additional energy cost over the existing process as shown in Figure 12. In addition, the capital cost of the unit will be lower than that of the proposed MVR because a compressor is not required and the temperature driving forces can be higher resulting in less heat transfer surface area.

Thus, consideration of the waste minimization process as an integral part of the overall process using pinch techniques results in a solution that costs less to buy and operate than the original proposal which appeared to be an attractive proposition.

The Future

Pinch Technology is certain to play a key role in addressing environmental issues over the next few years. The major benefit of the pinch-base approach is the establishment of targets prior to design. It is clearly a simple conceptual step from energy targeting via the composite curves to emissions targeting. Linnhoff March is currently working on a major U.S. emissions project with the utility company in order to set realistic, rather than arbitrary (and therefore unfair), emissions levels. By properly addressing the trade-off described earlier between the energy balance and the mass balance, it is possible to set equitable standards across a whole spectrum of diverse industries.

In Europe, we are currently working with a major German chemical manufacturer as part of an integrated team to assess the real opportunities for the reduction of CO₂ emissions over the next 10-15 years. This exercise embraces all processes operated by that company thereby allowing the full benefits of individual process optimisation together with site utility improvements.

We believe this demonstrates that the only way in which the emissions issue can be tackled seriously is to approach it in a truly integrated manner. Pinch Technology is the tool for successfully achieving this global solution.

Related Papers

1. Spriggs, H.D., R. Smith and E.A. Petela, "Pinch Technology: Evaluate the Energy/Environmental Economic Trade-Offs in Industrial Processes," Energy and Environment in the 21st Century, Massachusetts Institute of Technology, Cambridge, MA, March 1990.
2. Linnhoff, B. et al, "User Guide on Process Integration for the Efficient Use of Energy," Institution of Chemical Engineers, Rugby, U.K. (1982).
3. Linnhoff, B., G.T. Polley and V. Sahdev, "General Process Improvements Through Pinch Technology", Chemical Engineering Progress, pp 51-58, (June 1988).

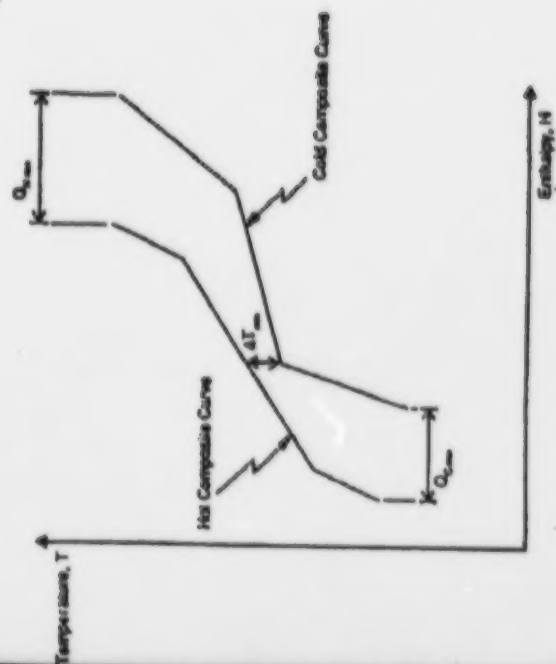


Figure 1 Composite Curves

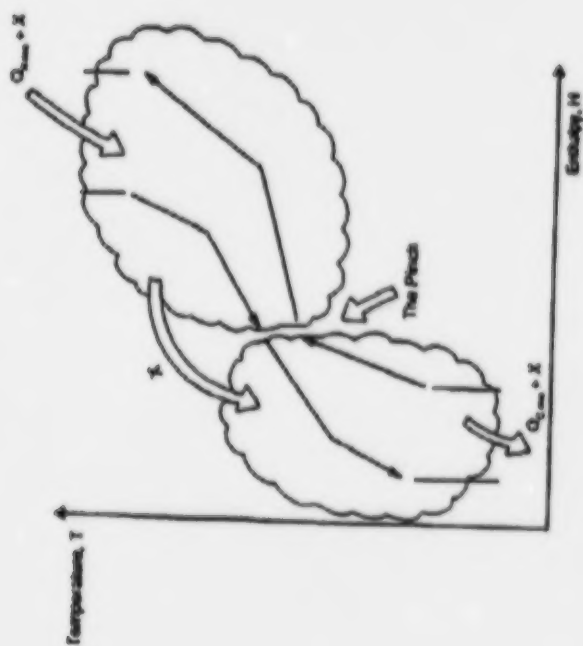


Figure 2 The Pinch

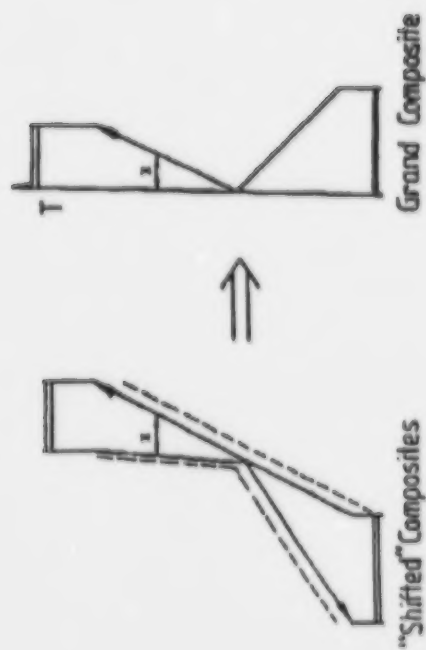
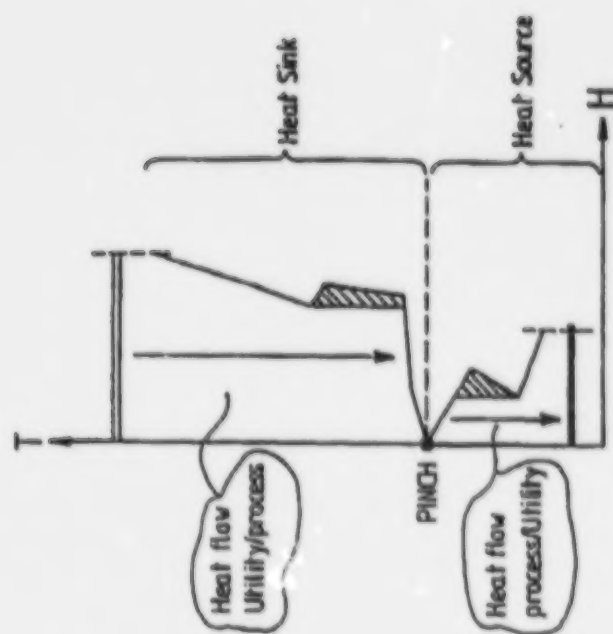


Figure 3 Construction of the Grand Composite Curve



The GRAND COMPOSITE CURVE

Figure 4 Use of the Grand Composite Curve for Utility Selection

CANADIAN PINCH APPLICATIONS

**ALBERTA GAS ETHYLENE
ALCAN
DUPONT
ENERGY, MINES & RESOURCES
HEINZ
LABATT'S
MOOSEHEAD
ONTARIO HYDRO
PETRO-CANADA
POLYSAR
REDPATH SUGAR
SHELL
SYNCRUDE CANADA**

FIGURE 5

UMIST Research Consortium Members

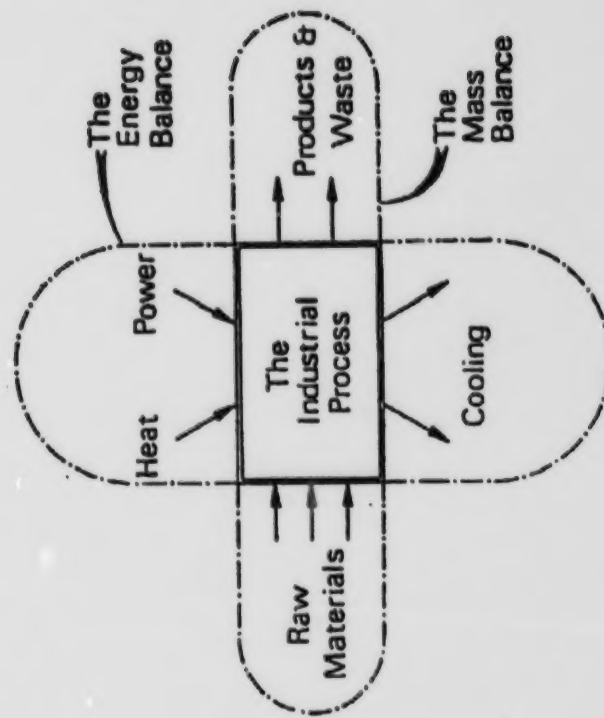
**ASPEN
BASF
Bayer
BOC Cryopplants
BP
DSM
EPRI
Exxon
Kellogg
KTI
Linnhoff March
Mitsubishi
Neste
Norsk Hydro
Shell
Union Carbide**

Figure 6

Developments in Pinch Technology

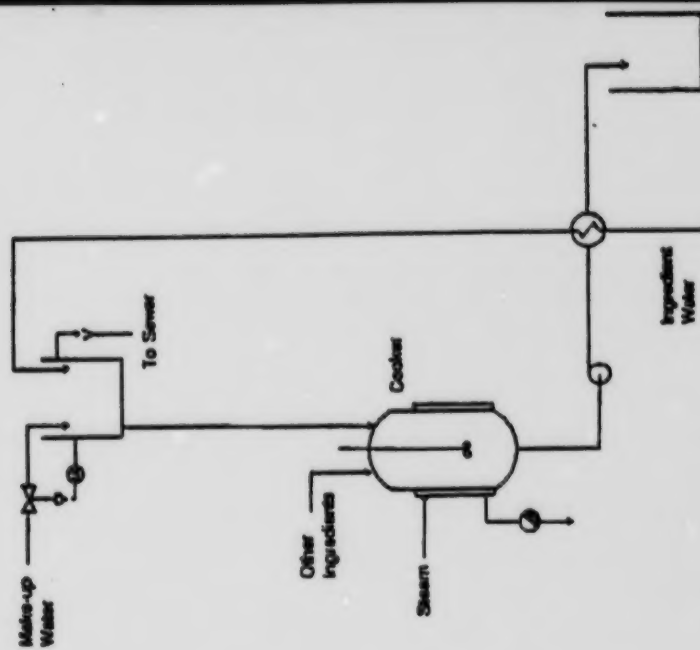
1978 Pinch
1980 Pinch Design Method
1981 Grand Composite Curve
1981 Distillation
1981 Heat and Power
1983 Process Changes
1984 Capital Cost Targets
1985 Retrofit
1986 Flexibility
1987 Furnaces
1987 Batch
1987 Constrained Targeting
1987 Multiple Utilities
1988 Pressure Drop Targeting
1988 Shaftwork Targeting
1988 Mixed Materials
1989 Area Matrix
1989 Column Grand Composites
1989 Network Optimisation
1990 Emissions Targeting
1990 Advent Software
1990 Waste Minimisation
1990 Batch Scheduling Software
1990 Energypop Software
1991 Exergy Techniques

Figure 7



Two fundamental "balances" are important to process design.

Figure 8 Fundamental Process Balances



Observed Water Use = 0.85 lb water/lb product
Predicted Water Use = 0.8 lb water/lb product

Figure 9 Simple Process Flow Diagram

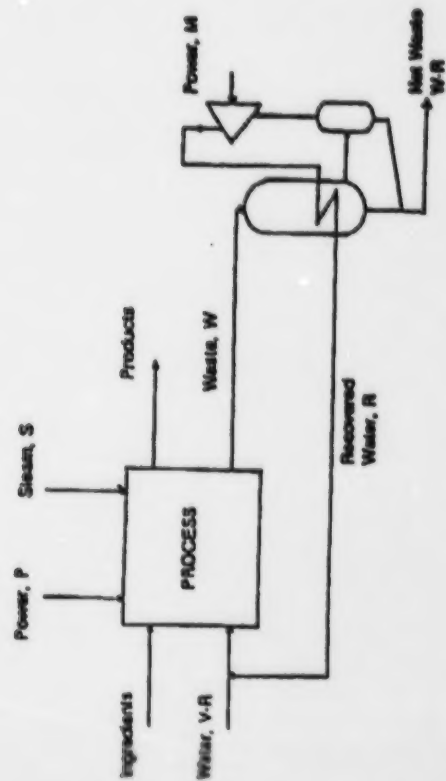
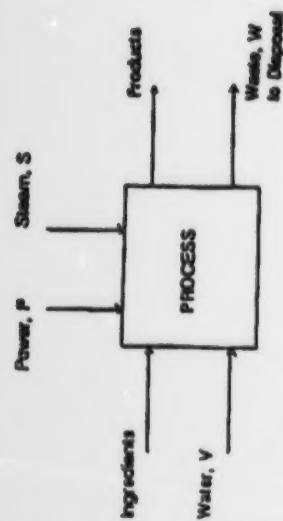


Figure 10

Proposed Use of Mechanical Vapor Recompression
Evaporator for Waste Volume Reduction

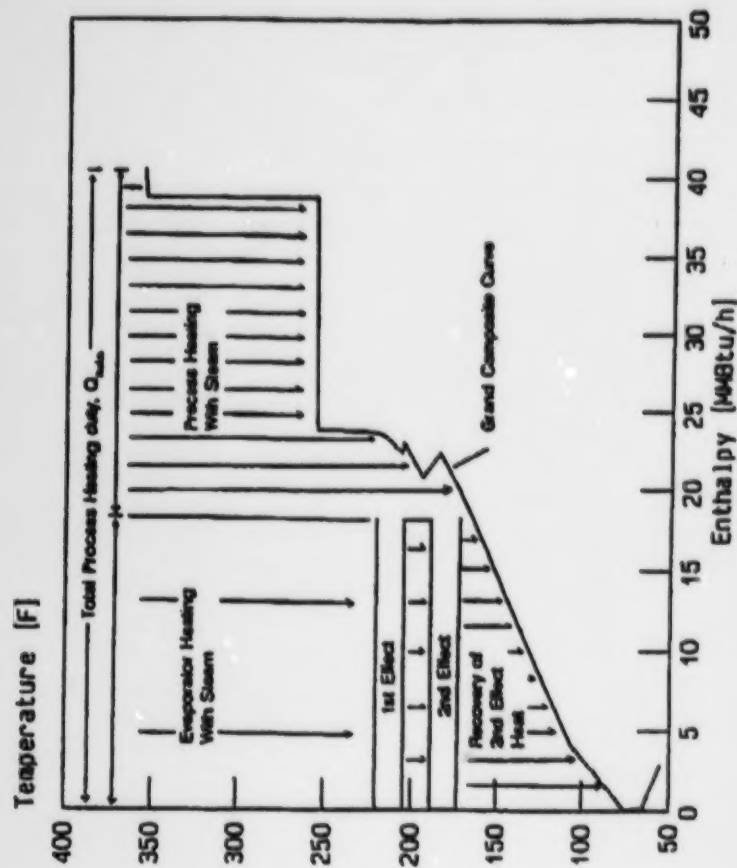


Figure 11

Grand Composite Curve for Soft Brisk Process
Show Evaporator Matching

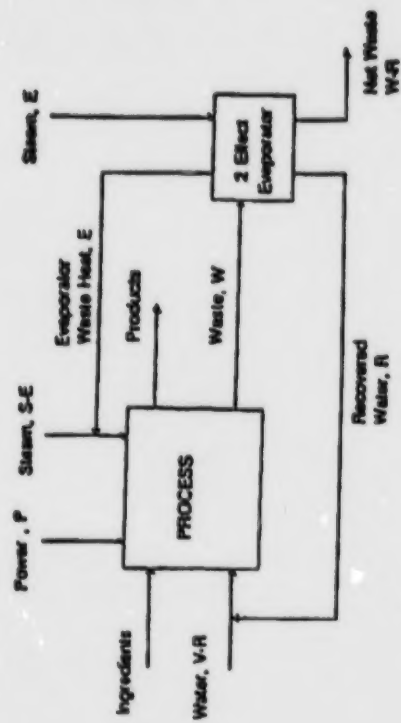
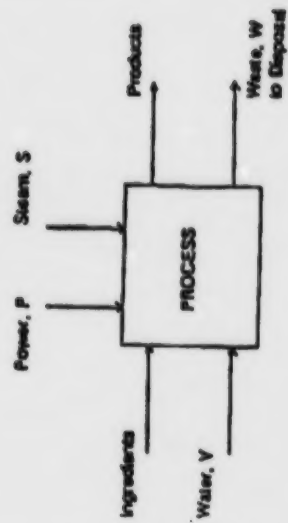


Figure 12. Process with Revised Evaporation Scheme

MARTIN H. MCCALL

Notes biographiques

Martin est, de métier, ajusteur-monteur de cellules/moteurs d'aéronefs. Après avoir obtenu son certificat d'aptitudes professionnelles, il retourna aux études et obtint, en 1962, un diplôme en Génie mécanique de la Sunderland Polytechnic. Il fut alors employé comme ingénieur de production dans une entreprise de fabrication de raccords à souder en métal forgé, de diamètre allant de 1/2 po à 36 po, destinés aux industries du gaz naturel, du mazout et du nucléaire.

Martin émigra au Canada en 1967, vécut un certain temps à Montréal puis fut employé par la Consumers Gas Company où il a occupé différents postes de surveillance et de gestion au cours des 24 dernières années. Il est présentement directeur de la section Residential and Commercial Technology du service Technology and Development.

Martin est un Ingénieur professionnel reconnu dans la province d'Ontario.

Biographical notes

Martin is an aero engine/airframe fitter by trade. On completion of his apprenticeship, he returned to school and graduated in Mechanical Engineering from Sunderland Polytechnic in 1962. After graduation he was employed as a Production Engineer in an industrial organization which produced forged welding fittings in sizes from 1/2" to 36" diameter for the natural gas, oil and nuclear industries.

He emigrated to Canada in 1967, lived for a while in Montreal and came to the Consumers' Gas Company Ltd. where he has held a variety of supervisory and management positions over the past 24 years. Currently he is Manager, Residential and Commercial Technology in the Technology and Development Department.

Martin is a registered Professional Engineer in the Province of Ontario.

"Gas Heat Pumps."

MARTIN MCCALL

Paper abstract

Gas heat pumps are a vehicle for providing more energy efficient heating and cooling from a single piece of equipment at a lower operating cost to the customer, while at the same time providing year round gas sales and enhanced load balancing for the gas utilities.

This paper presents an overview of many of the natural gas-fuelled heat pumps and chiller/heaters which are (a) available currently in the marketplace, (b) developments which are close to commercialization and under continuing research and development for future market introduction.

The Consumers' Gas Company Ltd. is actively involved in the pre-production prototype testing and the demonstration of available heat pump and chiller/heater technologies.

GAS HEAT PUMPS

by

Martin H. McCall, P. Eng.

Manager Residential and Commercial Technology

The Consumers' Gas Company Ltd.

Toronto, Ontario

Presented at the

Energy and Environment Conference

Canada Centre for Mineral and Energy Technology

Energy Mines and Resources Canada

March 20 - 21, 1991

at

The Sheraton Centre

Montreal, Quebec



Heat pumps are technological devices which provide heating or cooling, from a single self-contained piece of machinery. The device transfers or extracts energy from one location and delivers it to another location. The heat pump is an energy transfer system. Heat pumps are normally powered by natural gas or electrical energy. In this paper only those machines using natural gas for the whole or part of the process will be discussed.

Natural gas fueled heat pumps are available in two types of systems, absorption and vapour compression. The absorption types burn the natural gas fuel to change the state of the working fluid through direct energy transfer and the vapour compression types burn the natural gas fuel in a reciprocating engine to drive a compressor which in turn changes the state of the working fluid through compression and expansion. The engine-driven gas heat pump is similar to an electric heat pump, but in the natural gas engine-driven types the waste heat from the engine, is utilized to provide additional or supplemental heat during the winter, thereby increasing the system efficiency. In some instances the engine heat is sometimes also used to provide hot water for domestic purposes, year round. This style is in effect a triple integrated appliance.

A derivation from the absorption heat pump is the absorption chiller/heater system, produced primarily by the Japanese. The primary utilization of this device is as a gas-fueled absorption air conditioner, but it has the capability of providing low grade heat, which can be used during the shoulder months of the heating season to heat buildings, thereby avoiding the use of the central boiler system at their part load, lower efficiency, operation. The net effect is to improve the efficiency of the buildings' heating, cooling and ventilating system.

An example of a gas-fueled absorption heat pump cycle is illustrated in Slide 1 and the actual hardware is shown in the next slide,

similarly a gas engine-driven system cycle and hardware is shown in **Slides 3 and 4**. A chiller heater system is shown in **Slide 5**.

There are a variety of gas-fueled heat pumps available in the marketplace today for both the Residential and Commercial Market Sectors. Many more are being developed. A number of those, under development, are close to commercialization.

In the **Residential Market Sector** two systems are available currently. One is manufactured by **Dometic of Evansville, Indiana, USA**, the other by **Kool-Fire in Niagara Falls, Canada**.

Slide 6 is a composite, which shows an artist's rendition of the working components of an absorption air conditioning system. The illustration on the top left is a photograph of an actual cooling unit and below is the heating/cooling version. The **Dometic Systems** are not truly heat pumps, but rather a combination gas cooling/gas heating package. These units are readily available in Canada.

The **Kool-Fire** unit, shown on the next **Slide 7**, is manufactured in Niagara Falls, Ontario. The unique feature of this system is that it is basically an electric heat pump with the supplemental heat being provided through a very efficient gas burner which fires directly into and through the evaporator coil during those periods, in the heating mode, where the electric system is unable to provide sufficient heat for the residence. The compressor is kept running all of the time that the supplemental heat is being provided by the natural gas system. **Slide 8** shows the **Kool-Fire** system. All of the components, with the exception of the evaporator coil, are located outside the residence.

The **Arkla/Servel/Dometic** machine and the **Kool-Fire** system are single-effect machines which have relatively low performance efficiency, with cooling COP's in the region of 0.4 and gas heating efficiencies in the 80%-90% range.

A research effort is underway at **Domestic** to improve the cooling performance of the system through a component improvement approach. Pumps, higher efficiency electric motors and improved gas burner systems are being addressed. The goal is to improve the cooling performance COP from the existing 0.4 to 0.6. There is no known improvement research being conducted currently on the **Kool-Fire** unit.

There is research underway, funded through The Gas Research Institute (GRI) of Chicago to produce a residential gas-fired absorption cycle double-effect air conditioner/heater (DEACH).

The performance goals are:

- ° 3-ton refrigeration capacity
- ° Cooling COP = 0.95 for Proof of Concept (P.O.C.)
(Expect 1.0 for production units)
- ° 27,000 Btu/hr heating capacity
(50,000 to 65,000 Btu/hr with augmentation)
- ° Heating COP = 0.85
(expect slightly higher on seasonal basis)
- ° Weight less than 500 lbs.
- ° Parasitic power less than 750 watts
(not including air handler fan/controls)

A line sketch of the cycle is shown on **Slide 9** and an artist's impression of the package is shown in **Slide 10**.

In addition to gas absorption heating and cooling equipment, engine-driven gas heat pumps (GEHP's) are being developed for the US Market. Already a number of production models GEHP's are manufactured

in Japan for the Japanese market. In Canada and the US there appears to be no indigenous residential engine-driven gas heat pumps available commercially, although a number of designs have been under development in the past. A few, in the US, are close to commercialization. The Consumers Gas Company has been active in field evaluation of GEHP pre-production prototypes and our first residential engine-driven gas heat pump (a second generation research prototype from Japan) was evaluated in a residence in Toronto. **Slides 11 and 12** show the installation.

Another model, available commercially in Japan is currently being evaluated for a number of reasons but specifically to determine the technical changes required to North Americanize the unit. The most significant change required is, however, not specifically technical, but is rather one of reducing the first or owning cost. Furthermore the need for the Japanese systems to be as simple to service, as the North American heating and air conditioning products, is essential.

Slides 13 and 14 show the unit before and after installation. Currently data is being gathered on the performance on this machine.

In the USA, the development of a North American built gas engine-driven gas heat pumps is being funded by GRI.

The natural gas fueled **residential** heating and cooling system offers improved space conditioning efficiency and comfort, with lower overall operating costs.

Battelle-Columbus Division is the research contractor for a 3-ton cooling, 53,500 Btu/hr heating capacity engine-driven gas heat pump. The pump has a seasonal heating efficiency of 123% (COP_h 1.7)* and a seasonal cooling efficiency of 125% (COP_c 0.9)*. Cooperating in the development are **York International Corporation**, a major Heating Ventilating Air Conditioning (HVAC) manufacturer, and potential commercialization partner, **Briggs and Stratton**, the world's highest volume engine manufacturer, **Honeywell Inc.**, a leader in residential

space-conditioning controls and **Copeland Corporation**, a major compressor producer for the HVAC industry. Currently 10 GHP's of these pre-production GHP units are installed throughout the continental US and testing is scheduled to continue into 1991. Performance, reliability and maintenance requirements are being monitored closely through the use of a computer-based data acquisition system. The field evaluation and testing will provide installation, operating and maintenance experience, as well as highlighting areas for possible improvement, before the technology is transferred to **York International** for commercialization.

After all of the field tests are completed, **York International** plans to execute a nominal 100-unit market demonstration, in conjunction with gas utilities, (commencing in 1992), to gain even greater operating experience. Subsequent to this market demonstration, it is anticipated the the GHP would become available commercially in early 1993.

Slide 15, shows the gas engine power module. **Slides 16 and 17** are sketches of the indoor and outdoor units and **Slide 18** shows the unit installed at one of the ten test sites. The physical dimensions of the outdoor unit are 36" high, 43" long and 38" wide.

* COP is measured based on gas input ONLY. Averaged for 20 cities, seasonal gas heating efficiency is 123% and seasonal gas cooling efficiency is 125%, including all cycling and defrost losses.

In the **commercial sector**, a variety of absorption air conditioners and chiller/heaters, (again mostly of Japanese origin) are readily available in North American, with a significant number having been installed in the US and Canada.

The **Yazaki Corporation** produces high-efficiency, double effect equipment in the smaller sizes up to 30 Tons.

The manufacturer of the **Yazaki** machines claims a maximum cooling COP of 0.95 in the double-effect mode and a heating efficiency of 83%. These chiller/heater units are designed for applications where chilled and hot water are used in a central air system. During the cooling operation the condenser is water cooled through the use of a cooling tower.

The individual units can be banked together to provide incremental capacities up to 150 Tons. **Slides 19 and 20** show the installation at the condominium.

The Consumers Gas Company has three CH D30 model 30-Ton units installed on the roof at a downtown condominium in Toronto. These units replaced 8 10-Ton **Bryant** air cooled, ammonia refrigerant, air conditioning machines, which had reached the end of their useful working life. The measured seasonal COP_c of the **Bryant** machines was 0.39.

The results obtained from the field test during the cooling season indicated an average COP, in the cooling mode of 0.86, which is within 10% of the claimed maximum. In the heating mode the measured efficiency was 83% which is in-line with the manufacturer's claims.

Hitachi, another Japanese manufacturer, supplies a wide range of absorption chiller/heaters, in capacities ranging from 120 Tons to 1,500 Tons of cooling and in heating capacities between 1,100 MBTU/h to 18,000 MBTU/h (hot water) from direct fired single or two stage

machines or steam-driven absorption machines. Some of these absorption chiller/heater units can be operated in the chilling and heating cycles simultaneously, however this requires the installation of a three-way valve and corresponding controls.

Hitachi chiller/heaters were first introduced into the US market in 1979 and a number have been installed in various locations throughout the United States. Depending upon local gas and electric utility rates operating cost savings of up to 50% over electric counterparts have been experienced.

In Canada three types of **Hitachi** absorption machines will be offered, direct-fired, exhaust gas heat recovery, and two-stage steam-driven types.

At present these machines are UL listed and approved but they are not CSA/CGA approved. Units installed in Canada will have to be given field approval in the short term. As and when sufficient numbers are installed CSA/CGA approval will be obtained.

Slides 21 and 22 show two of the models.

A dual fuel heat pump (DFHP) developed jointly by the Electrical Power Research Institute (EPRI) and Lennox Industries was introduced to the marketplace about one year ago, after testing of six pre-production prototypes, four under actual field conditions. The unit named the "Fuelmaster" consists of an electric heat pump combined with a gas furnace for backup or supplemental heating. The target market is **light commercial** at 7.5 to 10 Ton cooling capacities with heating capacities in the range 12.6 kW to 25.8kW. At COP of 2.43 in cooling and 1.9 to 2.9 COP in heating is claimed. The gas fueled supplemental heating unit has a claimed thermal efficient of 80%. A cutaway illustration of the package is shown in **Slide 23**.

Several **commercial market** gas heat pumps are at various stages of development, in the US, mainly through GRI funding. In Canada the

majority of the R&D work has been funded and conducted by the National Research Council, four universities, two of the major electrical utilities and the Canadian Electrical Association. The main thrust has been concentrated on electrically fueled machines, specifically ground source, air source and water source types have been addressed. Very little R&D work seems to have been conducted on **commercial market sector** and extremely little, if any, work has been funded on gas heat pumps. Internationally, in Europe, most of the work appears to be co-ordinated through the International Energy Agency, headquartered in the Netherlands.

A number of engine-driven gas heat pumps are being funded and developed under the auspices of GRI. The unit closest to commercialization for the **Commercial Market Sector** is being manufactured by **Aisin Seiki**, at their US headquarters in Detroit.

The overall objective of the current program is with the **Aisin Seiki** to develop and field test a SRT machine with a heating COP of 1.8 at 47°F and a cooling COP of 0.9 at 95°F.

At present ten prototype units are undergoing field evaluation at various geographic locations around the continent. These locations are shown on **Slide 24**.

One pump is installed at one of Consumers' satellite service stations and is shown on **Slide 25**. The unit has been operating since August 1990 and has performed flawlessly over the cooling and heating season, to date.

The analysis of data from several sites has indicated a cooling COP varying in the range 0.7 to 1.0 at 90°F. The average capacity ranges between 2 Tons and 5.5 Tons with the wide spread being attributed to short cycling and large swings in daily ambient temperatures. All of the data from the heating mode performances has not been analyzed but preliminary data indicates that the target COP of 1.8 at 47°F is being achieved.

Second generation research continues on the components, with influence from the field evaluations, and it is expected that the system will be available for market field test in 1992.

The Japanese have produced a number of engine-driven gas heat pumps for the commercial market and one interesting variation is the Sanyo 13RT Stirling engine powered device shown on Slide 26.

A number of other programs on the development of gas heat pumps and other technology are underway at the Gas Research Institute and a listing is provided below:

Chemisorption Technology - A project using this basic scientific technology has been initiated, and is co-funded by a major HVAC manufacturer. This essentially **residential** market sector technology is long term research. The concept is a solid/vapour system with a rapid reaction to produce temperature lifts at ambients of -10°F to 70°F. The proposed design will be compact and powerful.

Sorption Based Central Double-Effect Air Conditioner Heater.

This technology is undergoing technical review for feasibility.

Stirling Engine-Driven Gas Heat Pump

The object of this research is to develop a long life, low emission, engine-driven heat pump featuring external combustion technology to reduce cost and improve engine efficiency.

Rotary Engine Commercial Gas Heat Pump

The objective of this project is to develop a rotary engine-driven heat pump for commercial (10 RTon) applications - Exploratory applied research.

Solid/Vapour Adsorption Gas Heat Pump

This research activity is designed to develop a residential size solid/vapour (Carbon/Ammonia) adsorption heat pump. The short term goal is to produce a proof-of-concept prototype in the near future.

Solid/Vapour Adsorption Gas Heat Pump

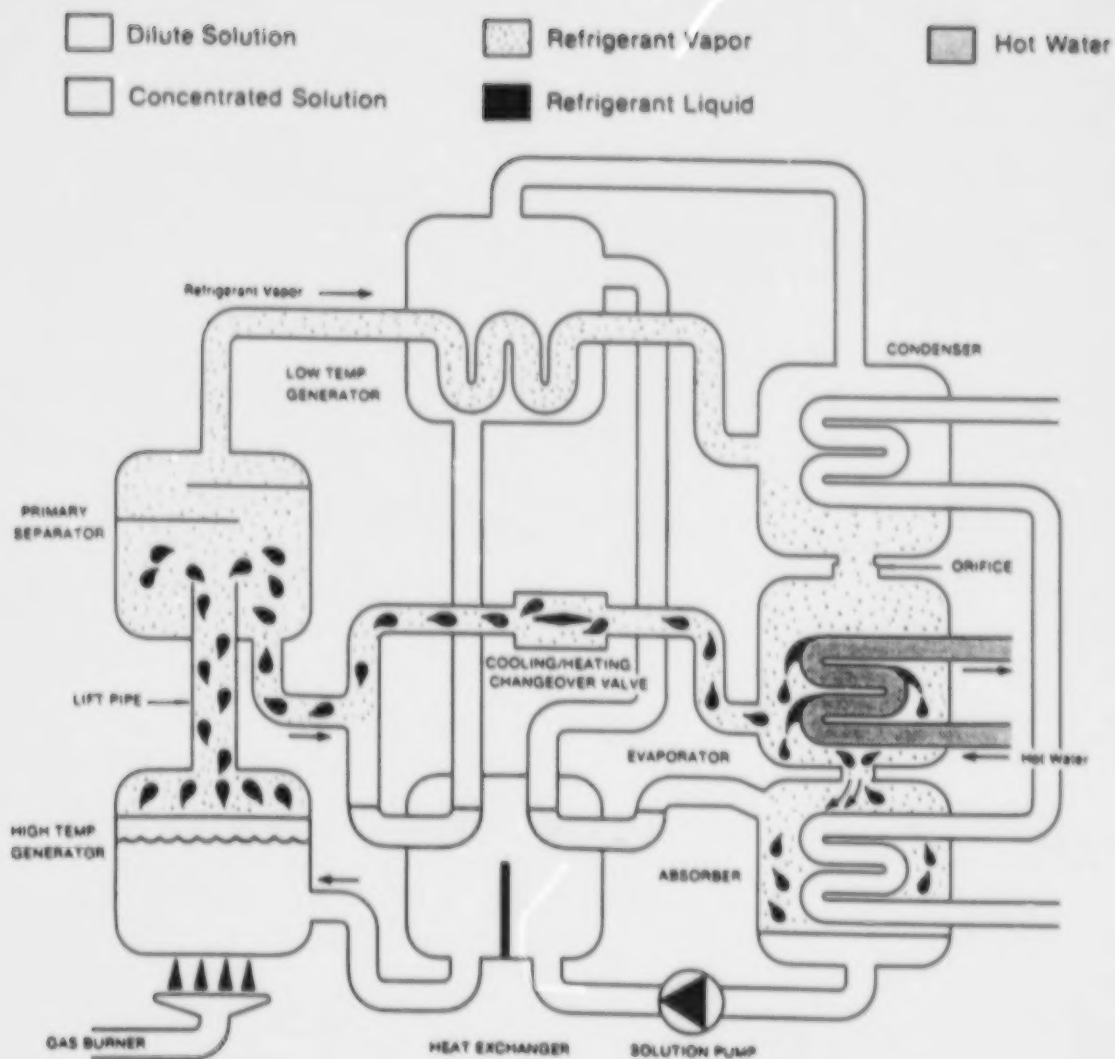
The objective of this program is the same as above except it uses Zeolite/water salts as the working substances. This is technology based R&D.

Currently tests are underway to determine the structural integrity of the breadboard components.

- Slide 1 Gas Fueled Heat Pump Absorption Cycle
- Slide 2 Example of a Commercial Sized Heat Pump
- Slide 3 Engine-Driven Gas Heat Pump Components
- Slide 4 Engine-Driven Gas Heat Pump Installation
- Slide 5 Yazaki
- Slide 6 Artist's Impression of Absorption Air Conditioning System
- Slide 7 Kool-Fire
- Slide 8 Kool-Fire System
- Slide 9 DEACH
- Slide 10 DEACH
- Slide 11 Installation of Second Generation - GHP
- Slide 12 Completed Installation
- Slide 13 Japanese Heat Pump Outside Components
- Slide 14 Japanese Heat Pump Installed at Site
- Slide 15 Engine-Driven Gas Heat Pump Power Module
- Slide 16 Residential 3RT Engine Driven GHP - Outdoor Unit
- Slide 17 Residential 3RT Engine Driven GHP - Indoor Unit
- Slide 18 Field Test Site

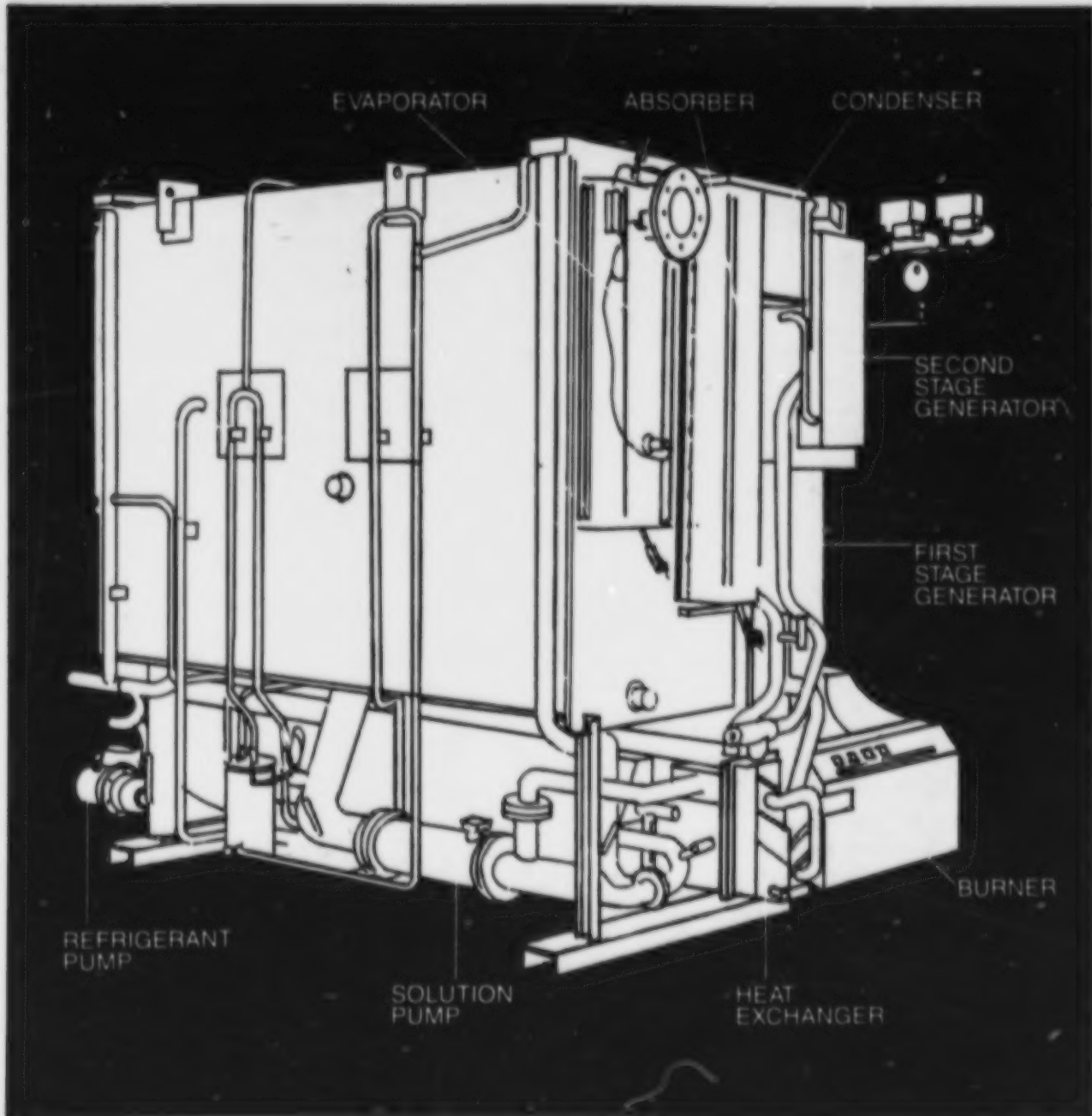
- Slide 19** Yazaki Roof Top Installation (Toronto Condominium)
- Slide 20** Close-Up of Unit at Condominium
- Slide 21** Hitachi Exhaust Heat Receover Chiller/Heater
- Slide 22** Hitachi Direct-Fired Chiller/Heater
- Slide 23** "Fuelmaster" Combination Gas/Electric Heat Pump
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- Slide 25** Aisin Seiki Prototype under Field Evaluation
- Slide 26** Experimental Stirling Engine Powered Heat Pump

SLIDE 1



Gas Absorption Cycle
(Chiller/Heater)

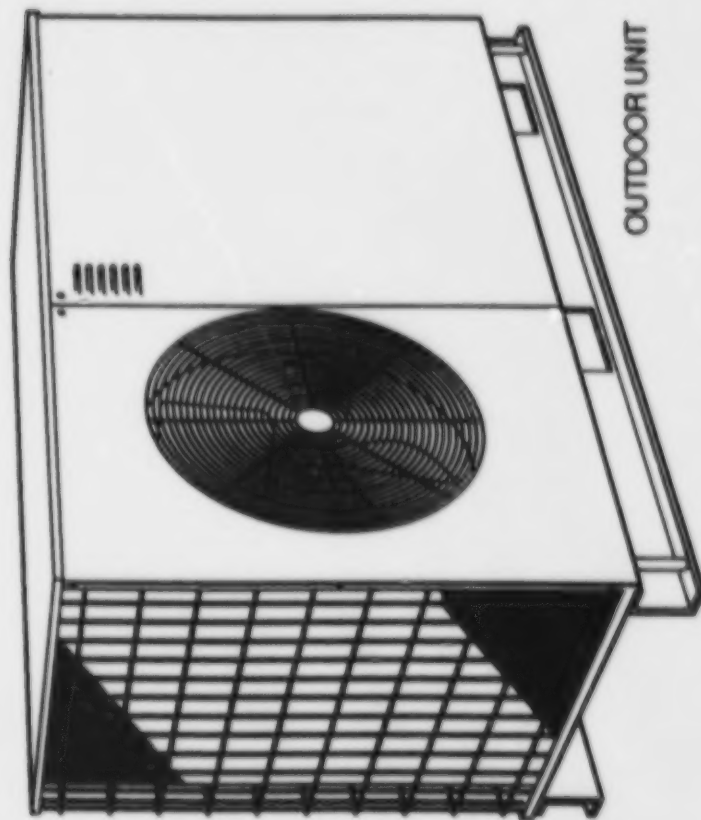
SLIDE 2



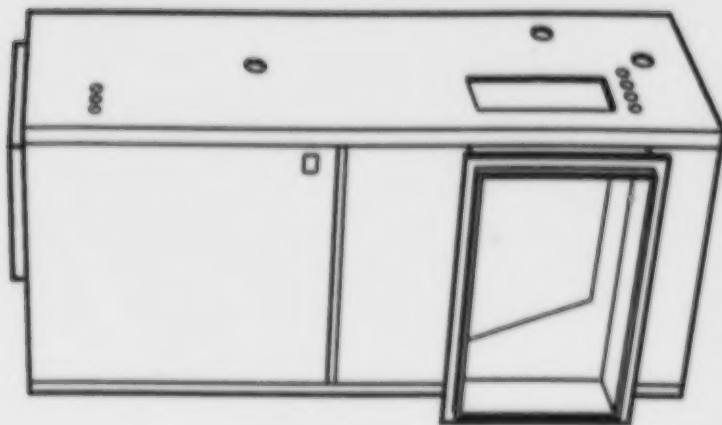
Example of the Components of a Commercial-Sized Direct Fired Gas Absorption Heat Pump (Chiller/Heater)

SLIDE 3

AISIN Gas Heat Pump



OUTDOOR UNIT

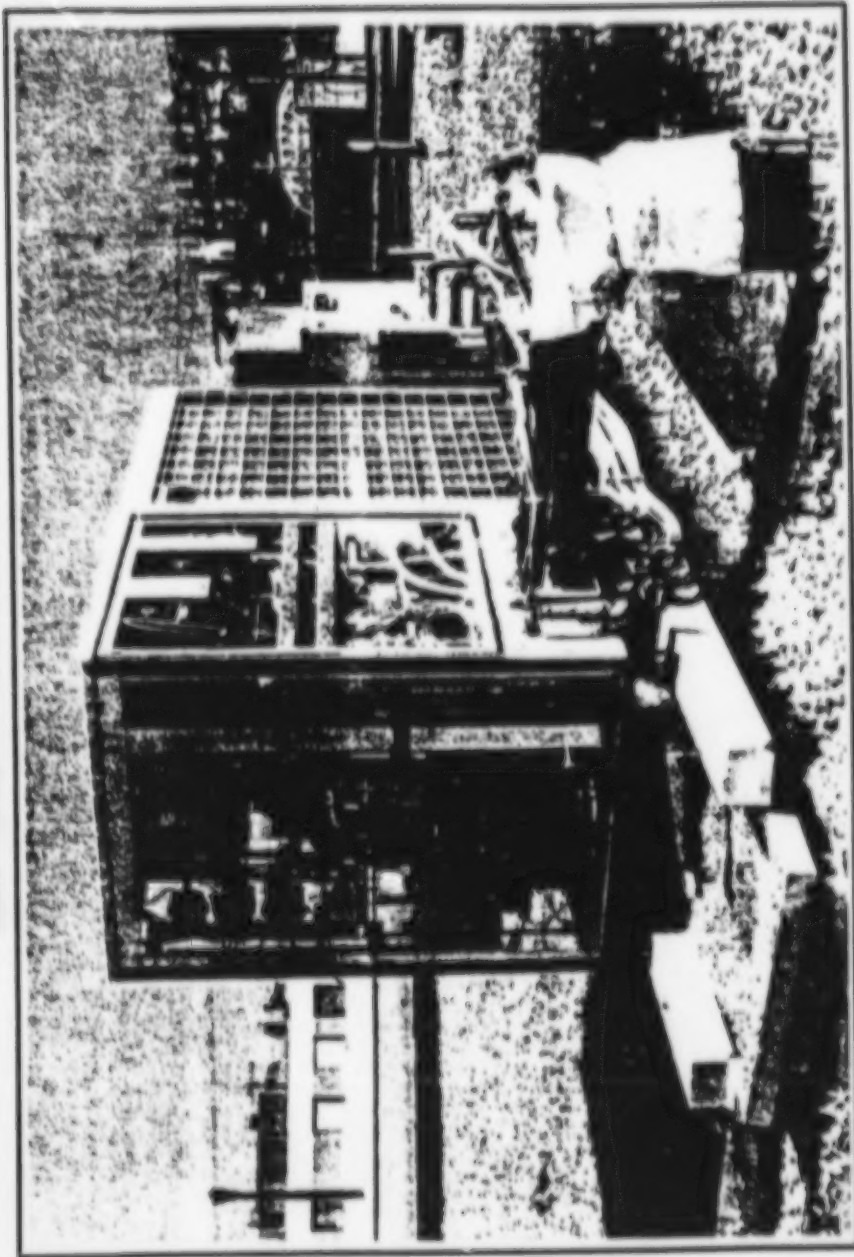


INDOOR UNIT
(Free-standing duct type)

Engine-Driven GHP Components

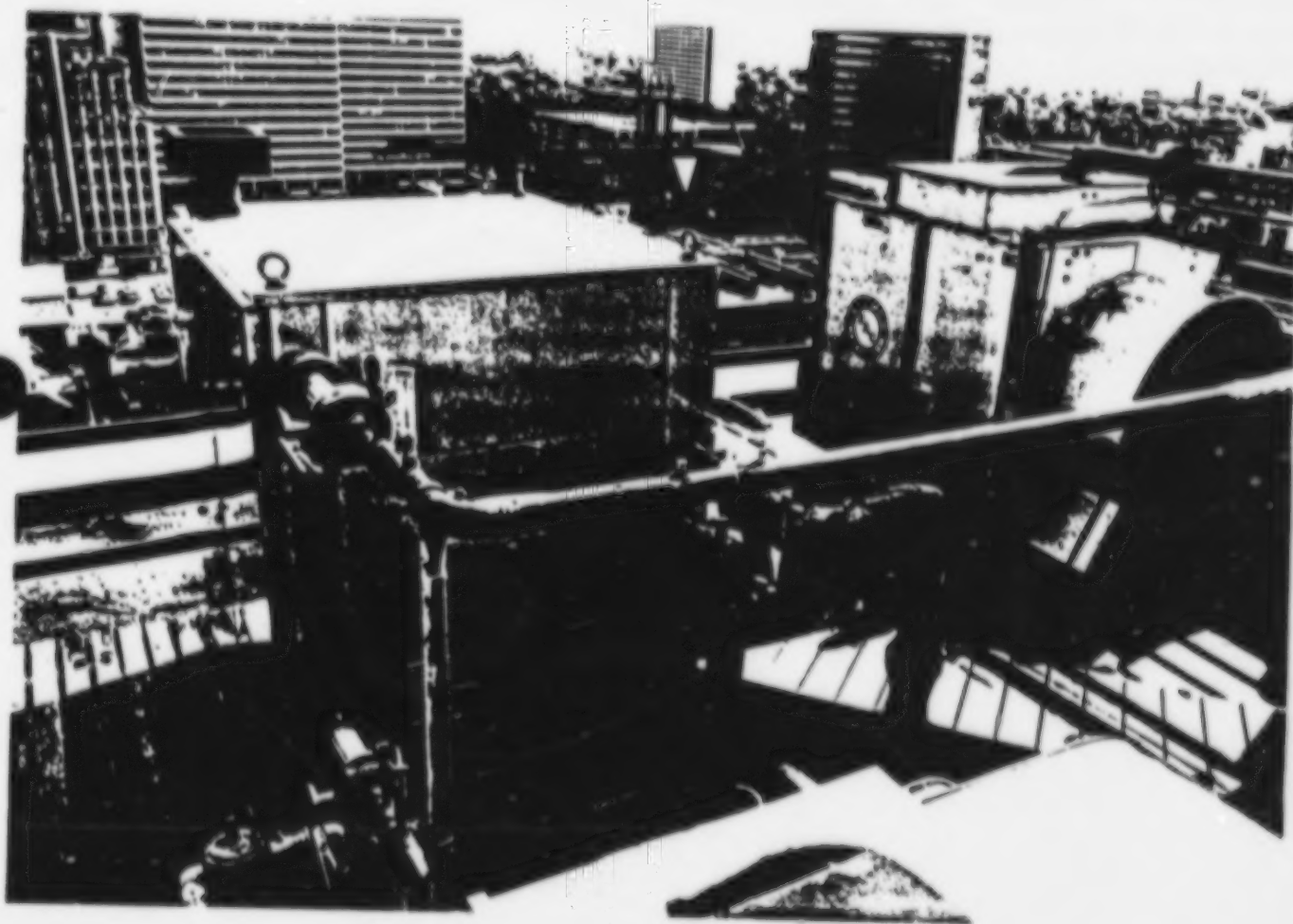
SLIDE 4

EQUITABLE SITE



Engine-Driven Gas Heat Pump Installation

SLIDE 5

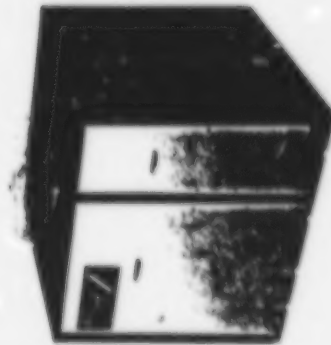


A Chiller Heater System
(Yazaki)

Gas Air Conditioning

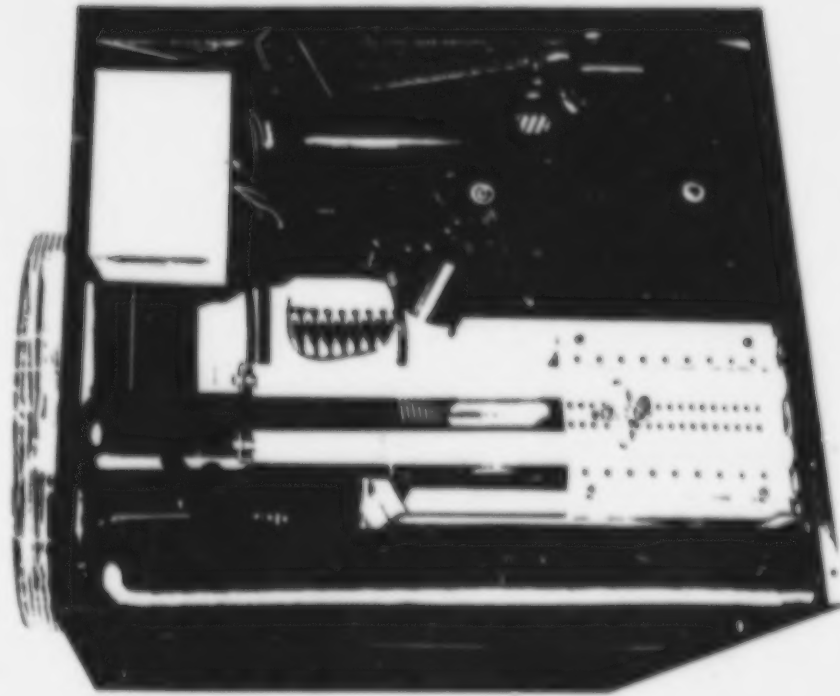


Gas Fired Chiller
Air cooled 3 to 25 tons
comfort or process cooling



Durable unit-body construction,
tough weather resistant finish

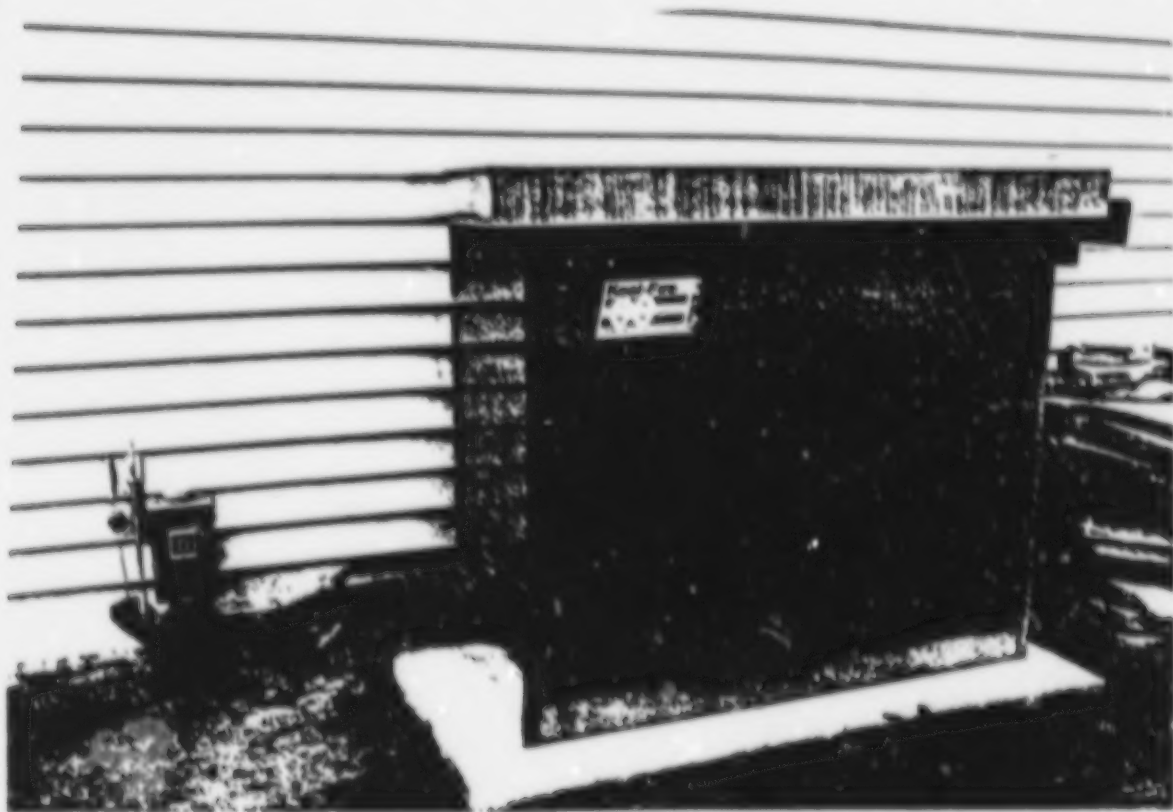
Energy-saving pump drive motor



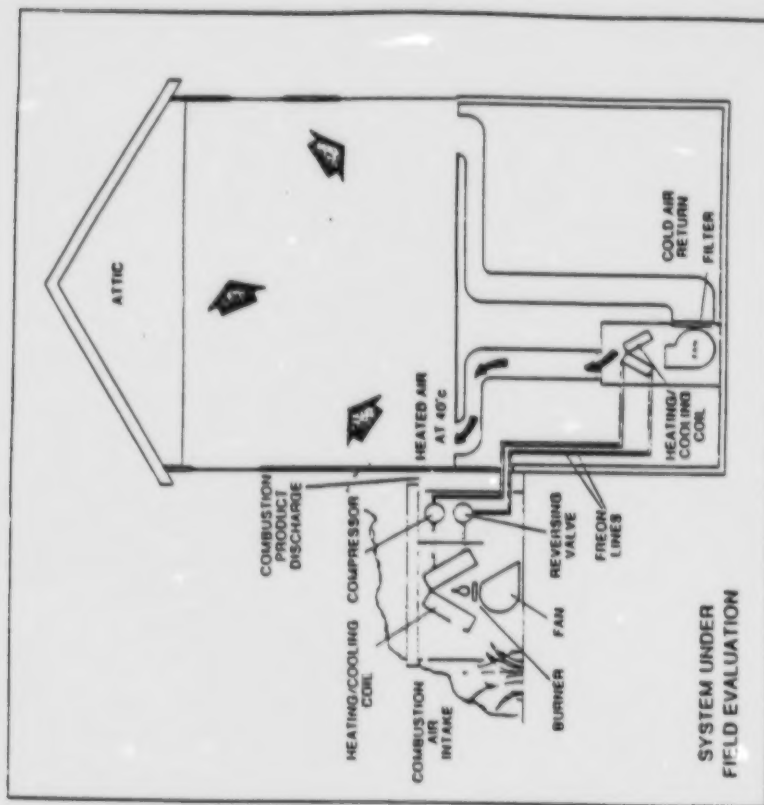
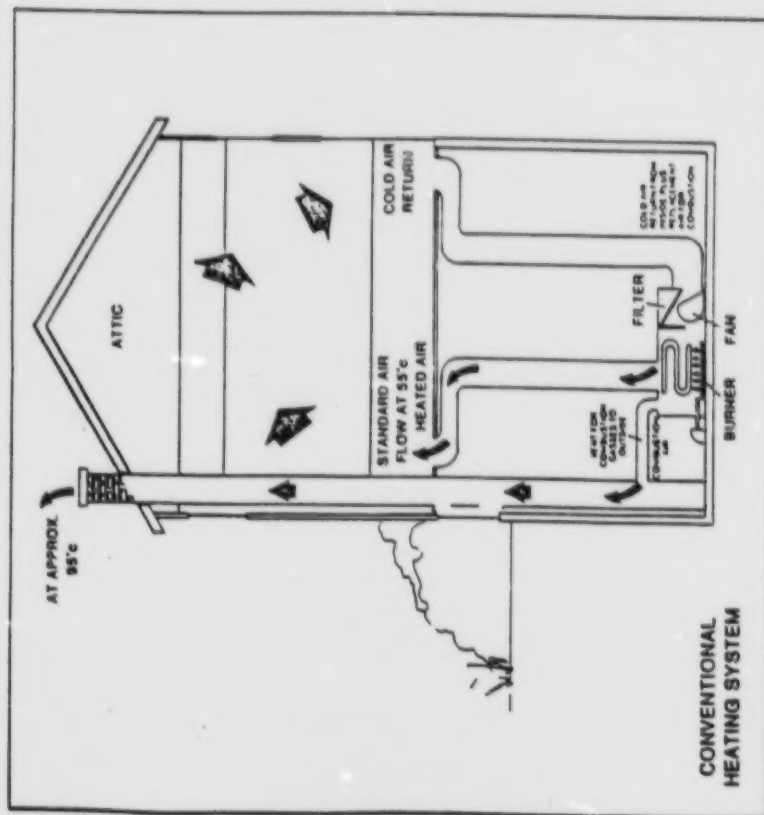
Efficient chrome-lined generator
eliminates the need
for a compressor

Only three moving parts in the
sealed refrigeration unit

SLIDE 7

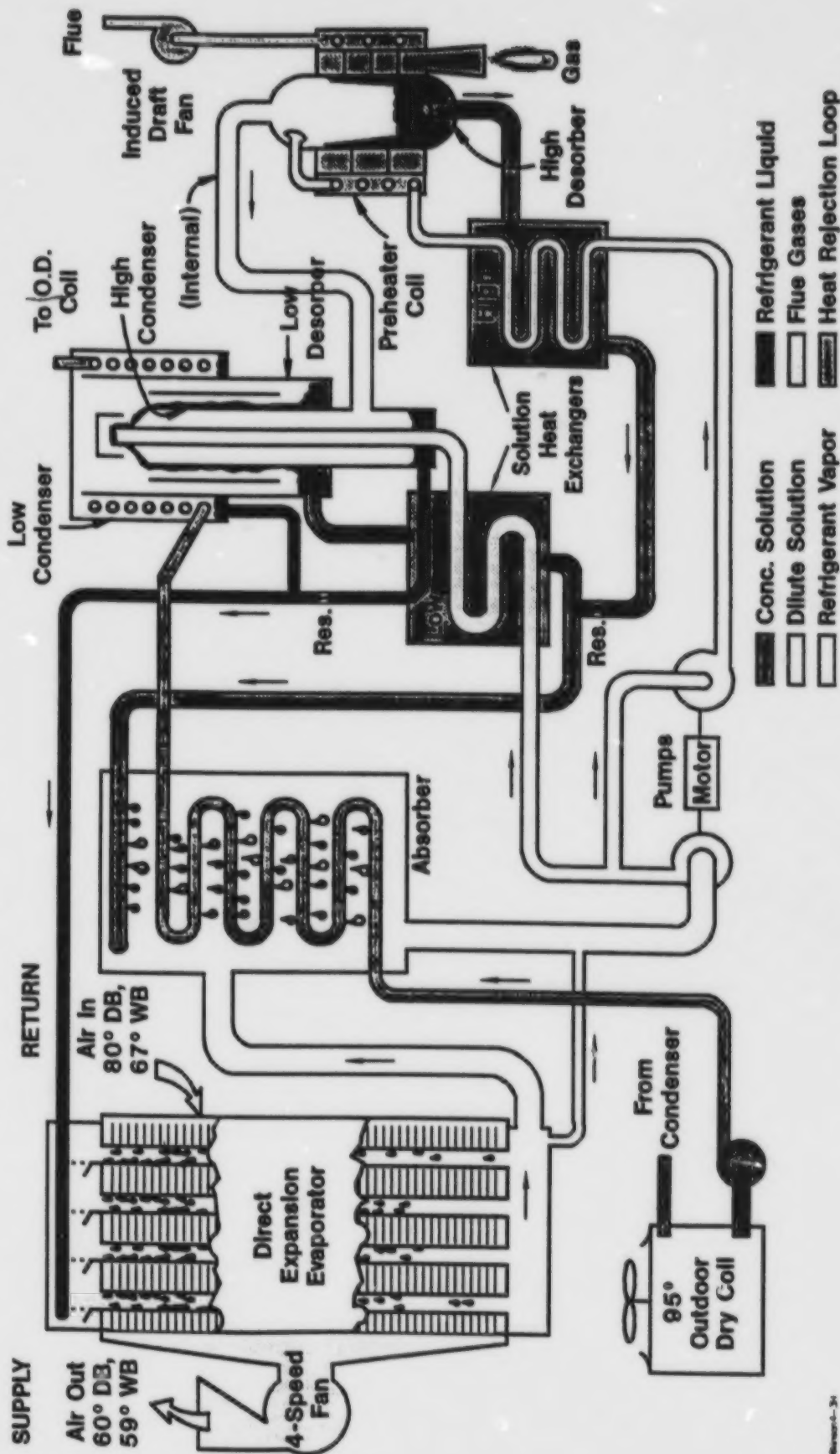


SCHEMATIC OF CONVENTIONAL SYSTEM AND SYSTEM UNDER TEST



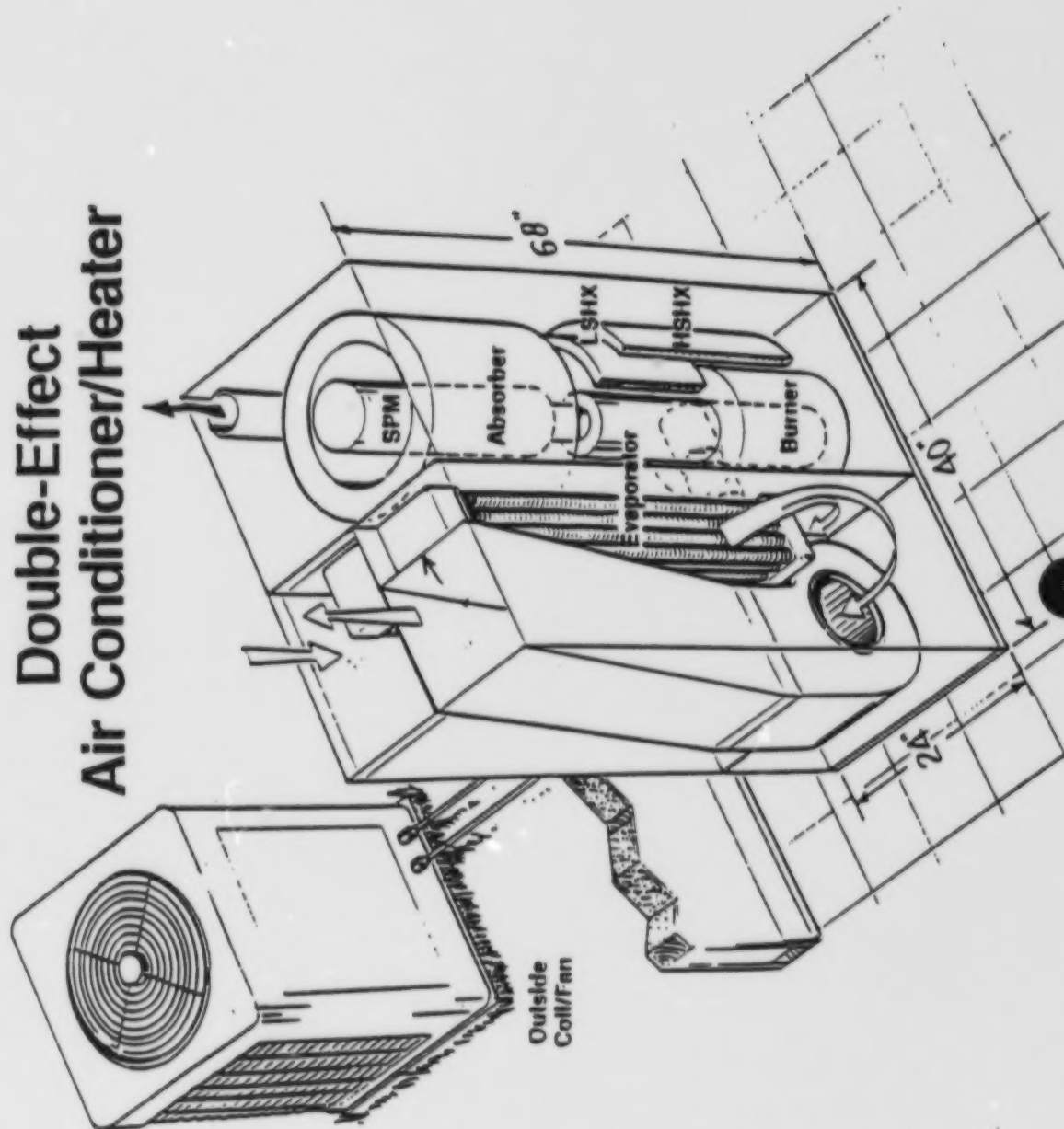
SLIDE 9

Cycle of Operation - Cooling Mode

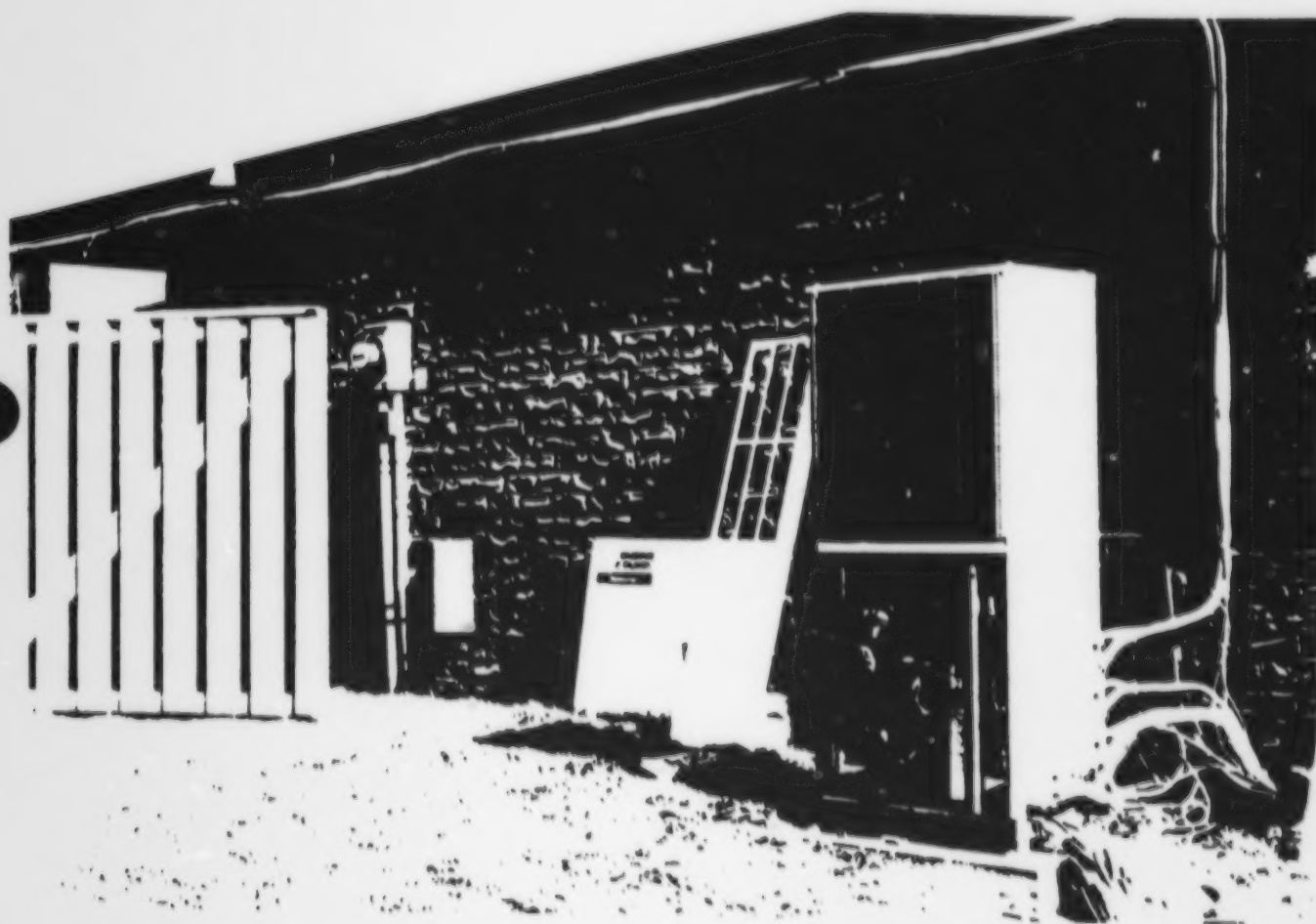


SLIDE 10

Double-Effect Air Conditioner/Heater

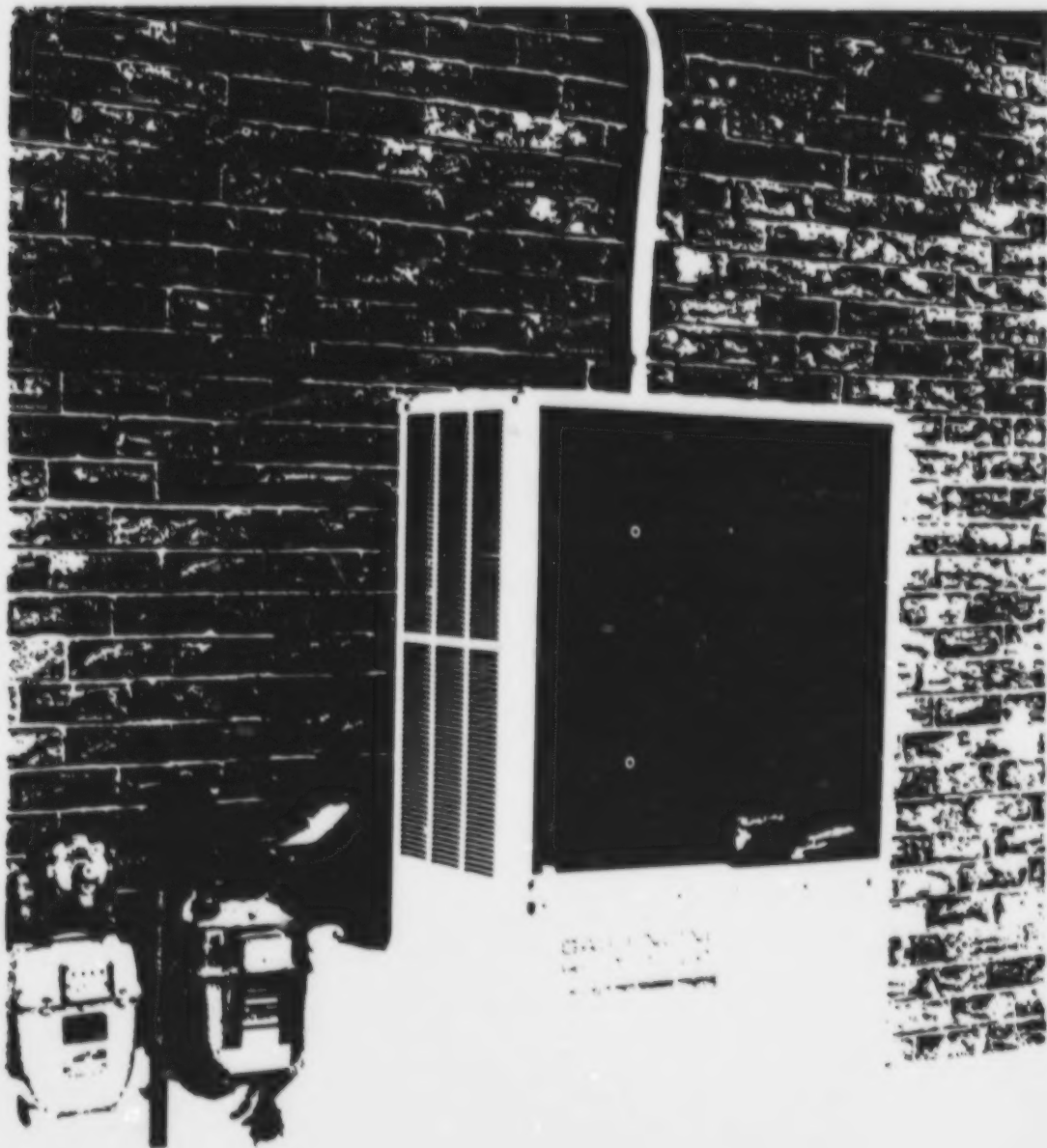


SLIDE 11



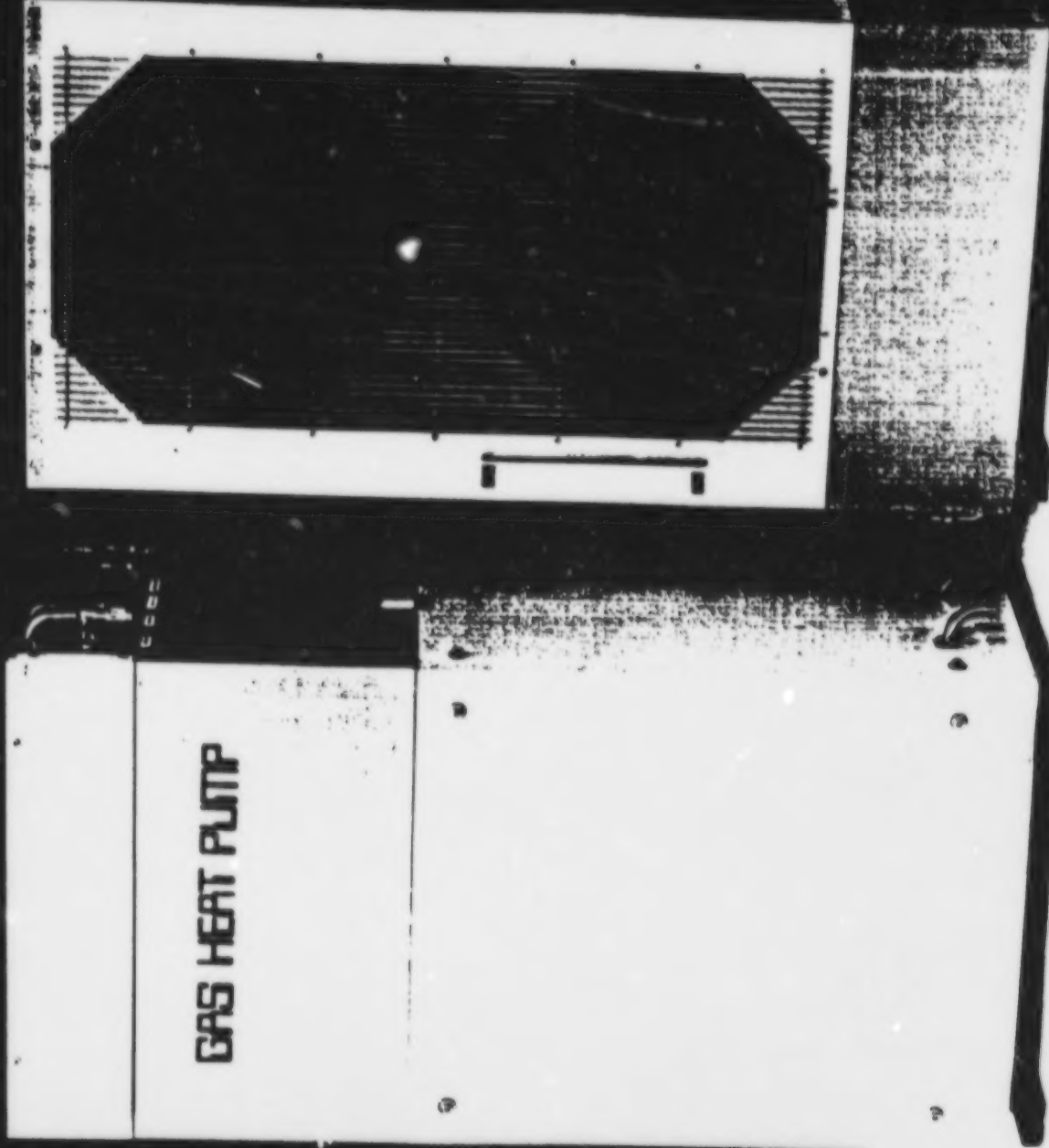
Installation of Second Generation Research Prototype Gas Engine-Driven
Heat Pump

SLIDE 12



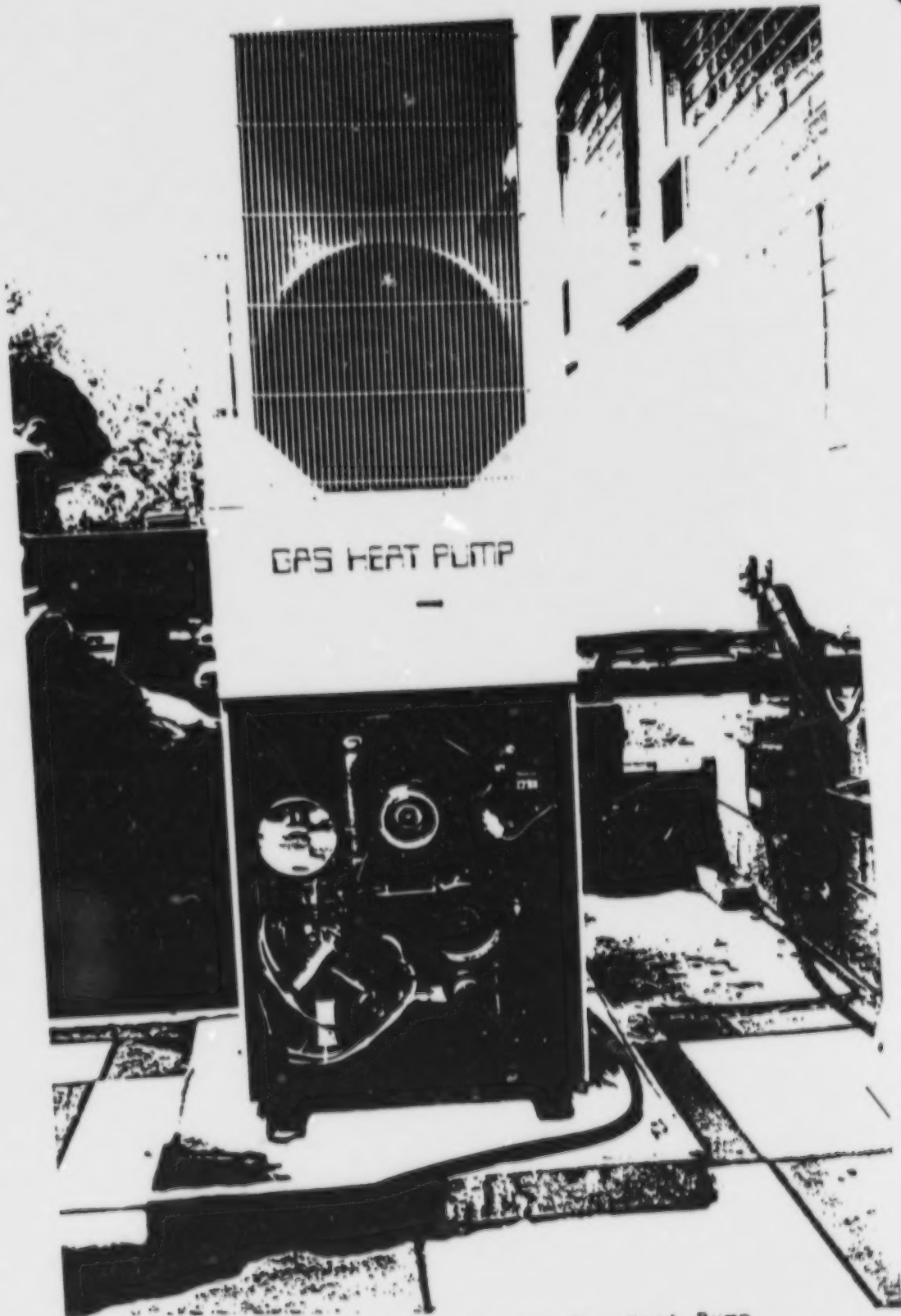
Computer Installation

SLIDE 3



Japanese Engine-Driven Heat Pump Outside Components

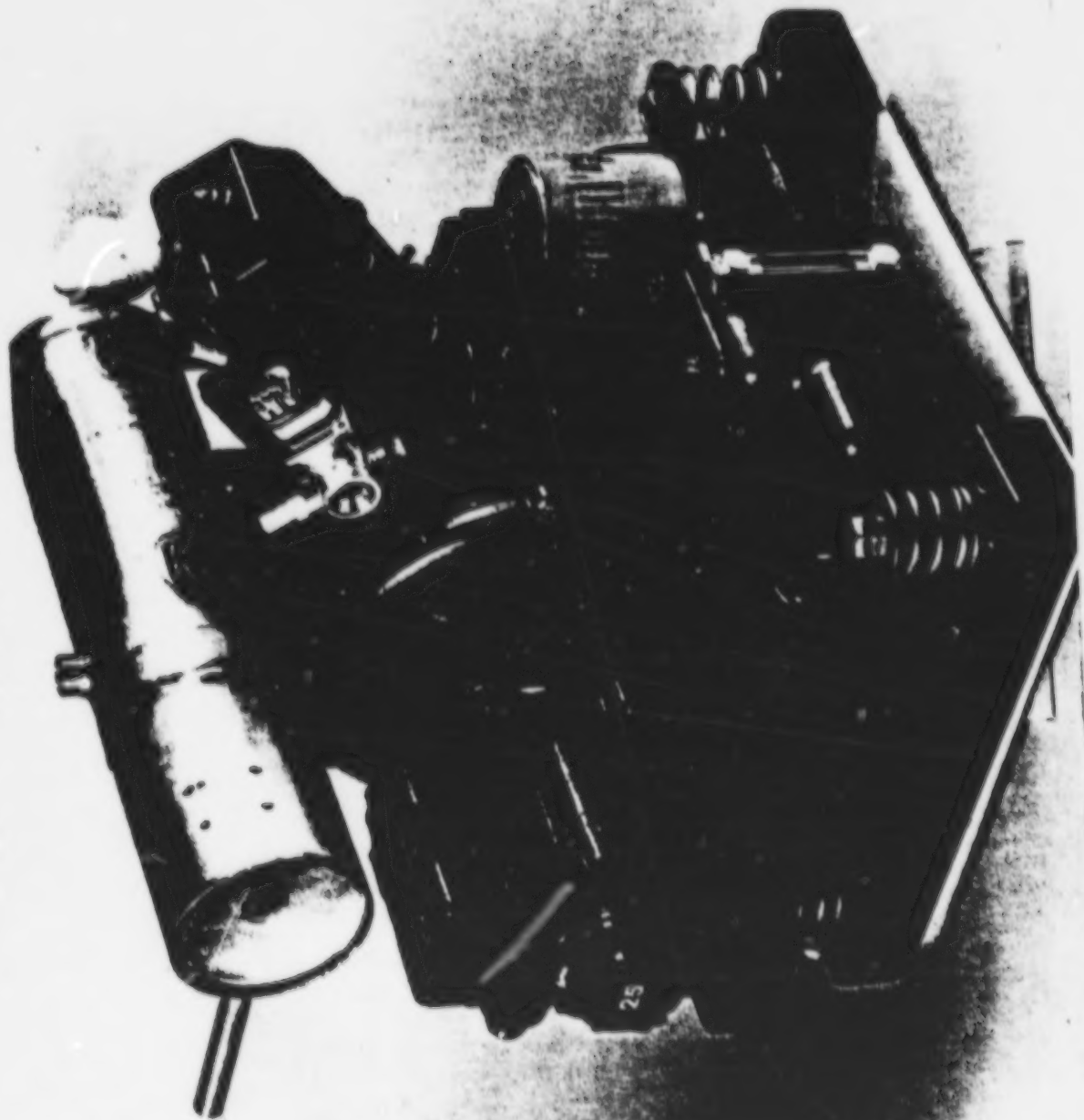
SLIDE 14



GAS HEAT PUMP

Japanese Residential Engine-Driven Gas Heat Pump
Installed at Site

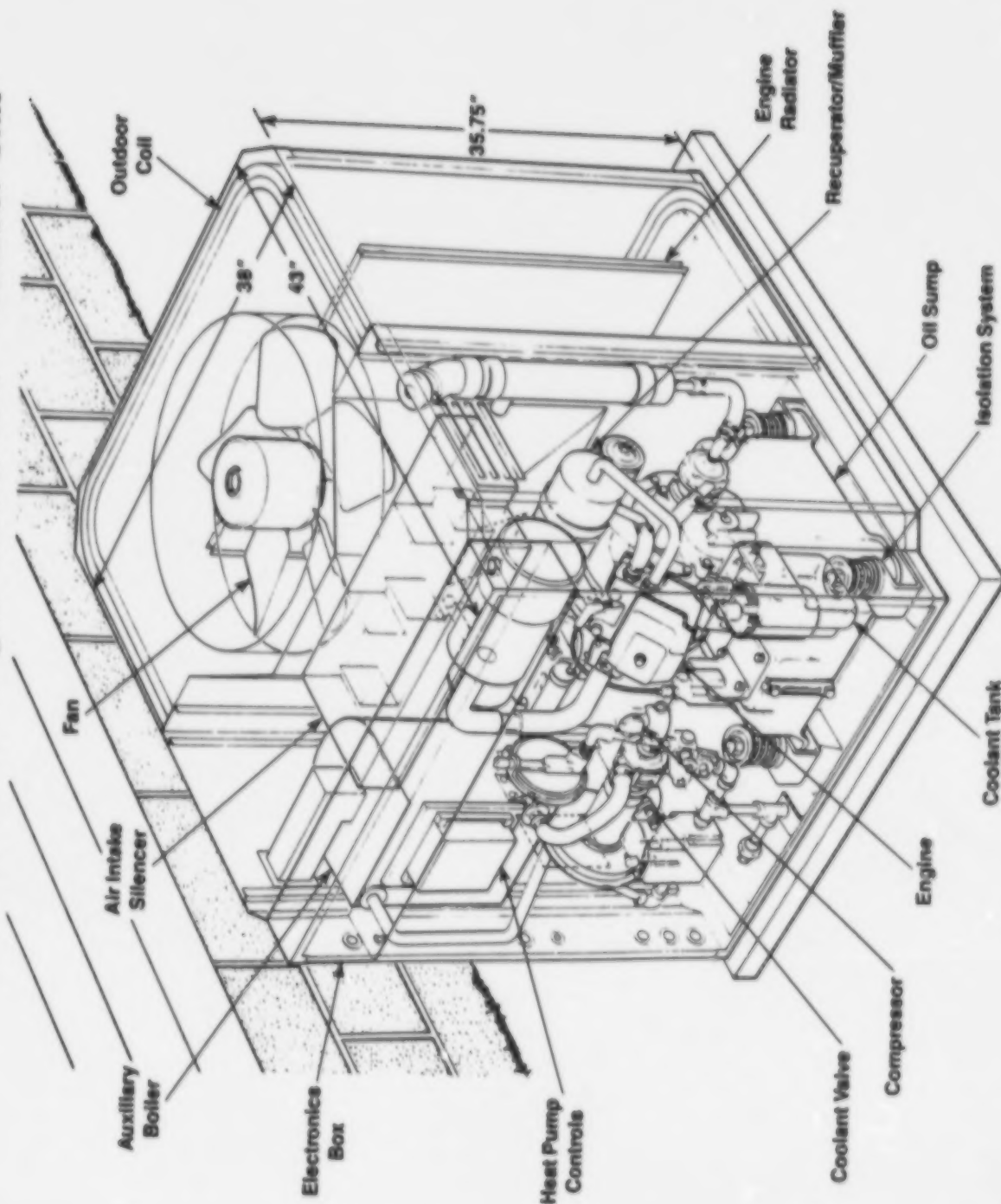
Slide 15



Engine-Driven Gas Heat Pump Power Module

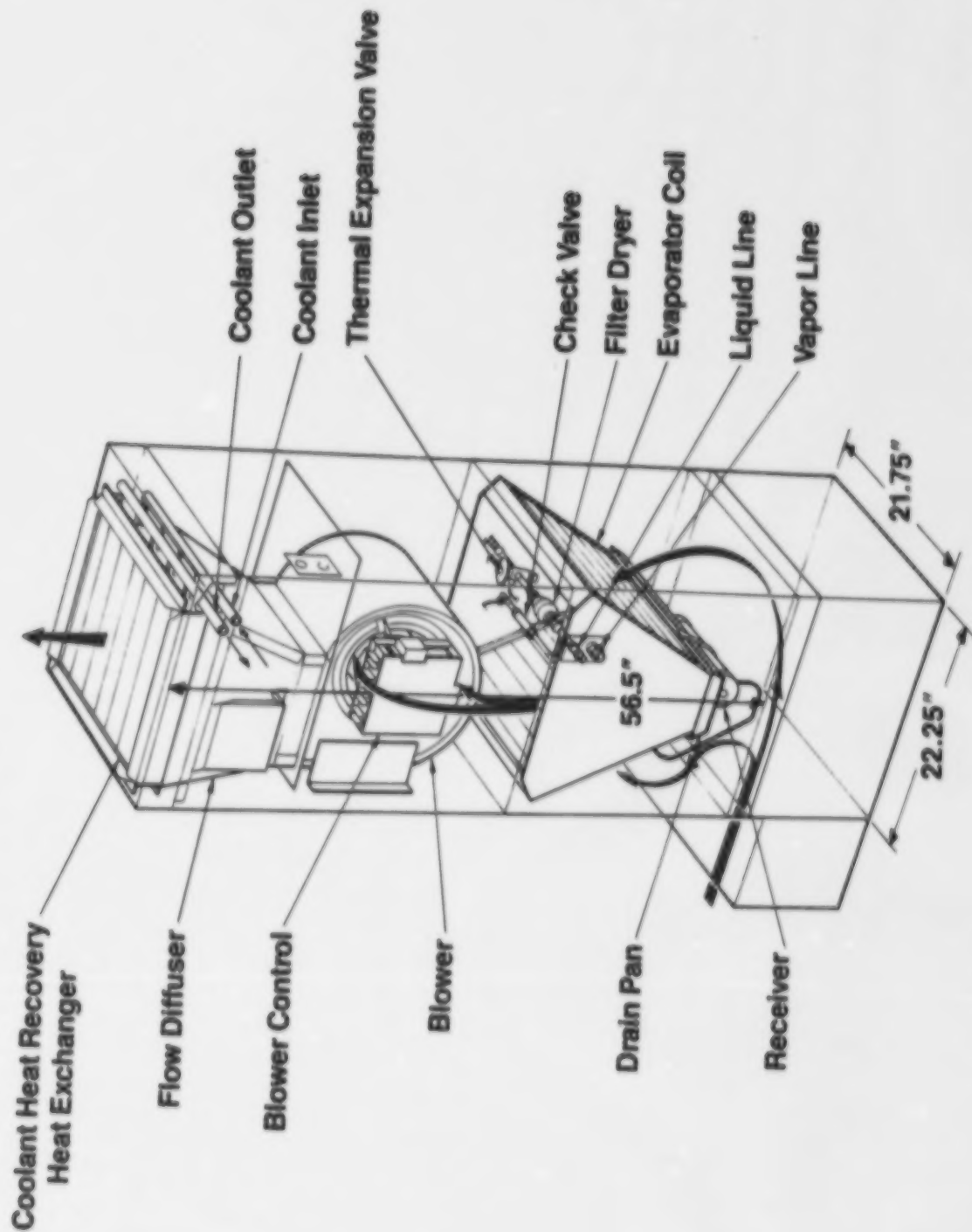
Slide 16

Residential 3RT Engine Driven GHP - Outdoor Unit

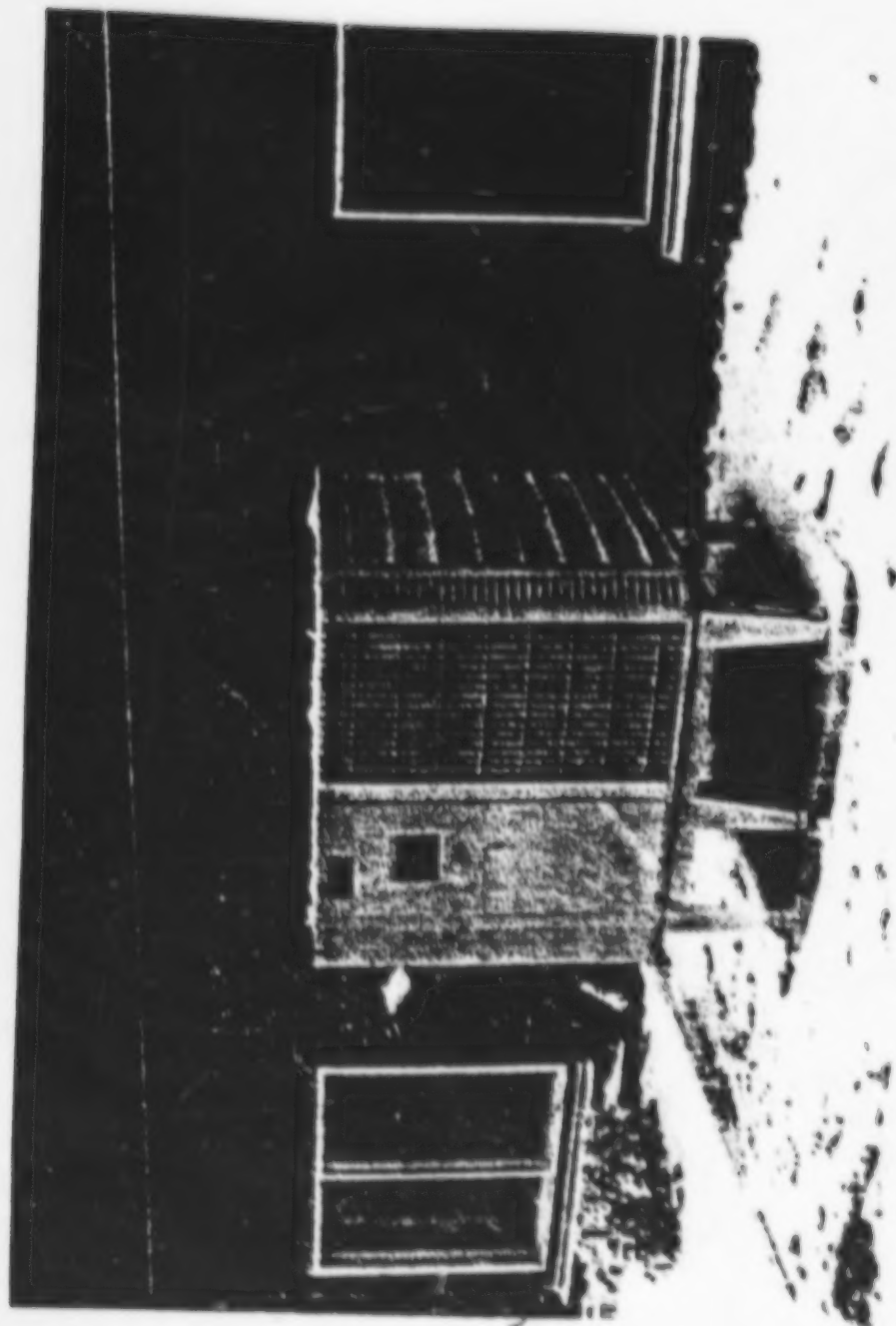


Slide 7

Residential 3RT Engine Driven GHP - Indoor Unit



SLIDE 18



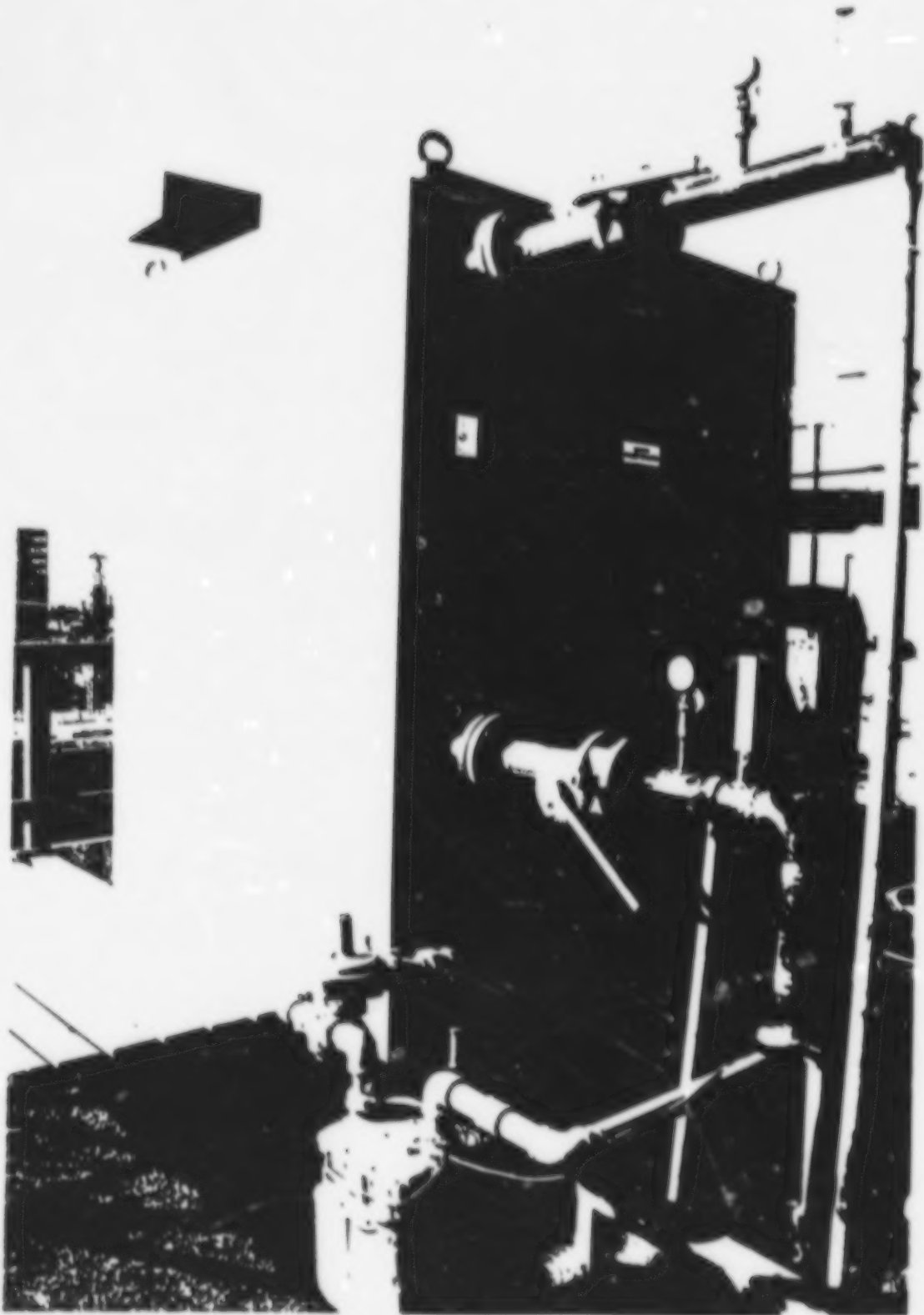
FIELD TEST SITE

SLIDE 19



Yazaki Roof Top Installation (Toronto Condominium)

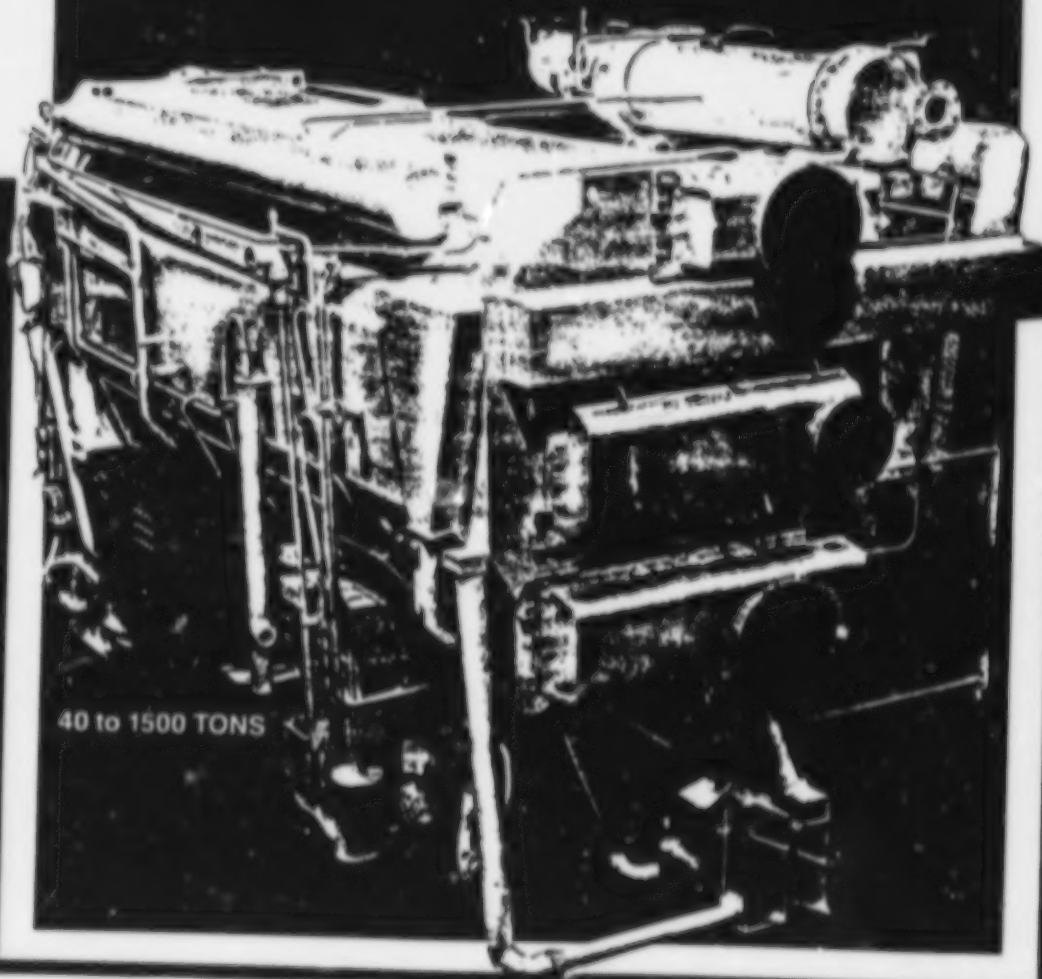
SLIDE 20



Close-Up of Unit at Condominium

SLIDE 21

Heat Recovery Chiller-Heater



Hitachi Exhaust Heat Recovery Chiller/Heater

SLIDE 22

**PARAFLOW cuts
cooling and heating costs
up to 50%**

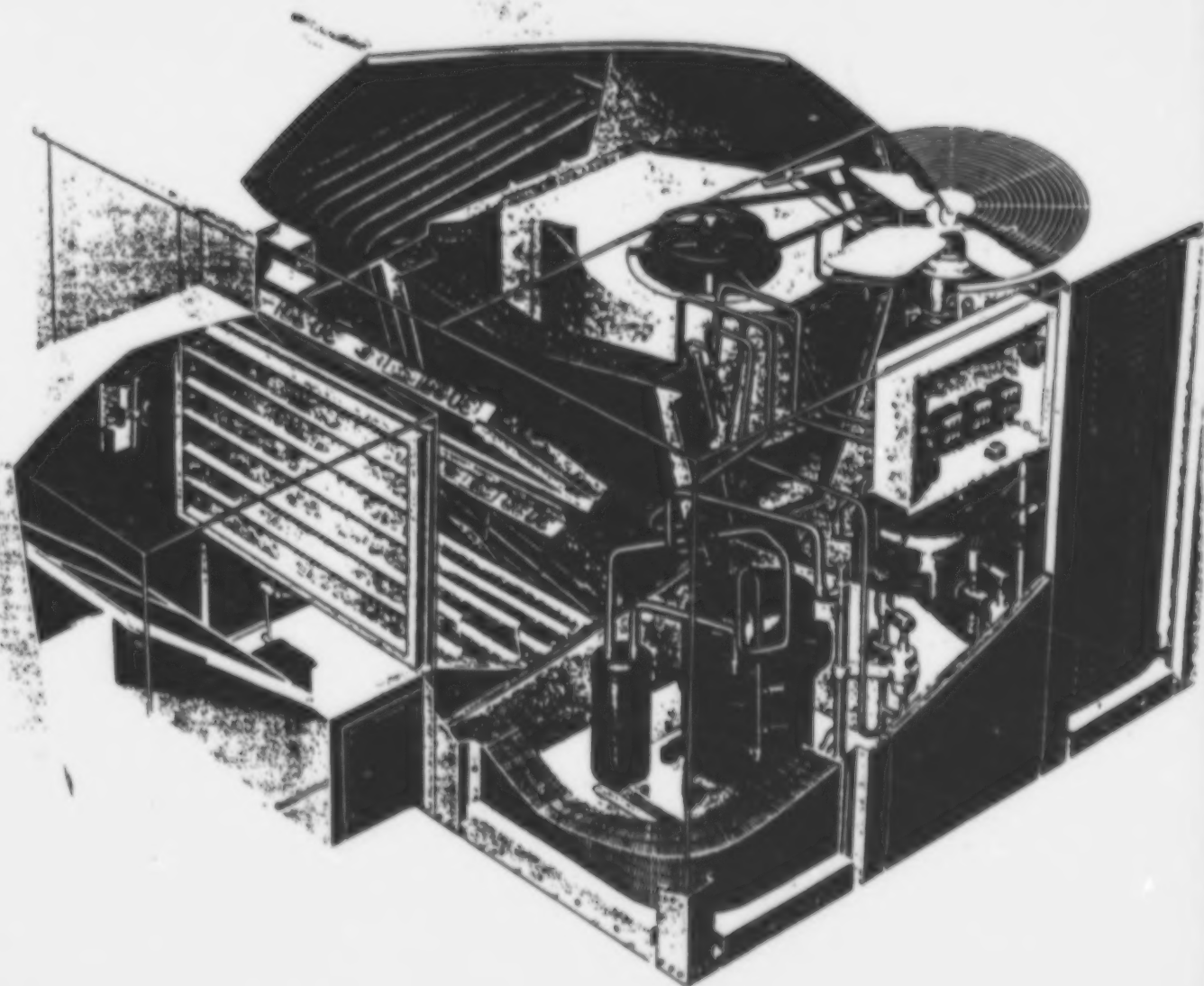


250 TO 1500 TONS

Hitachi Direct-Fired Chiller/Heater

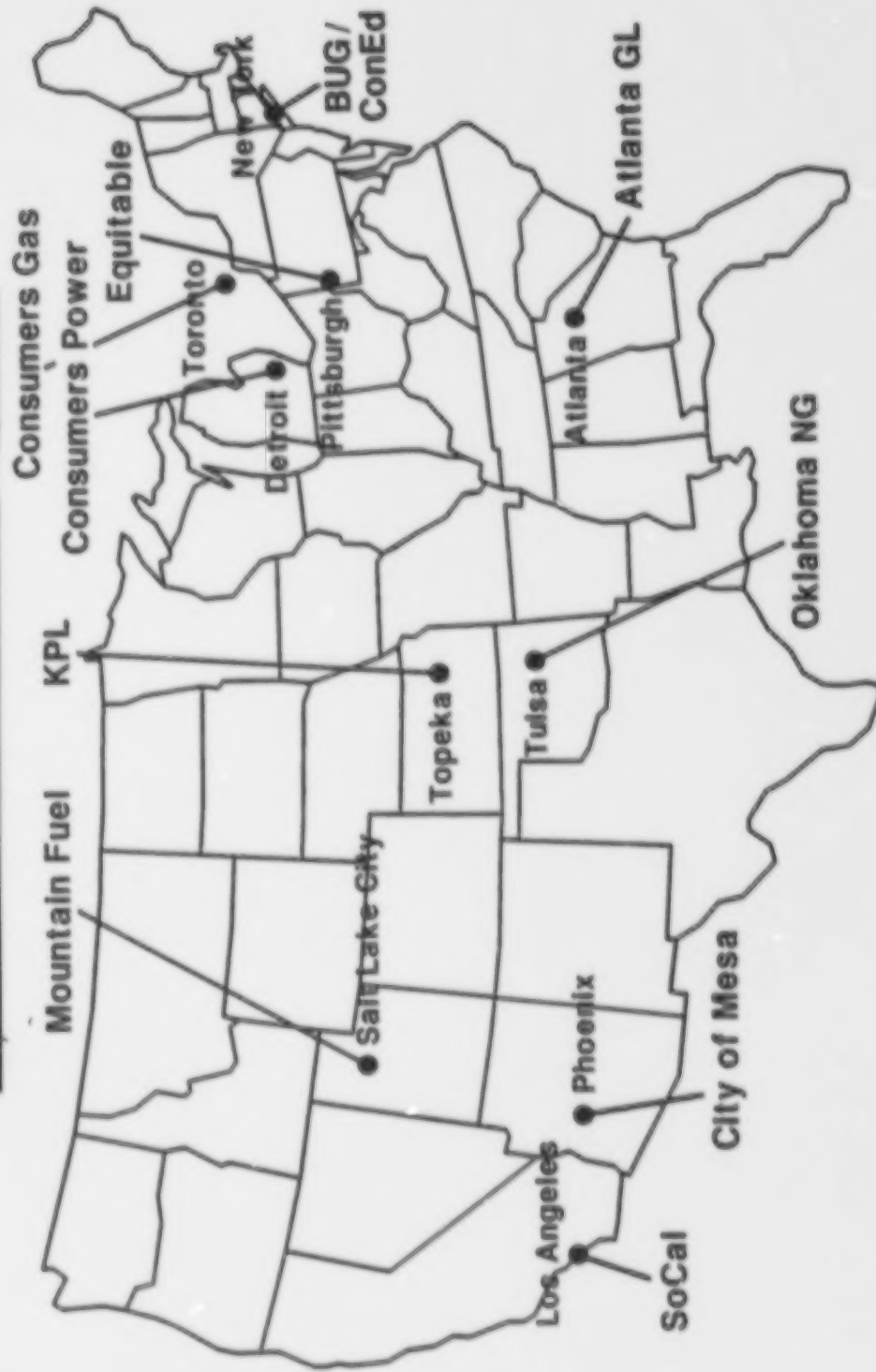
SLIDE 23

Dual-Fuel Option

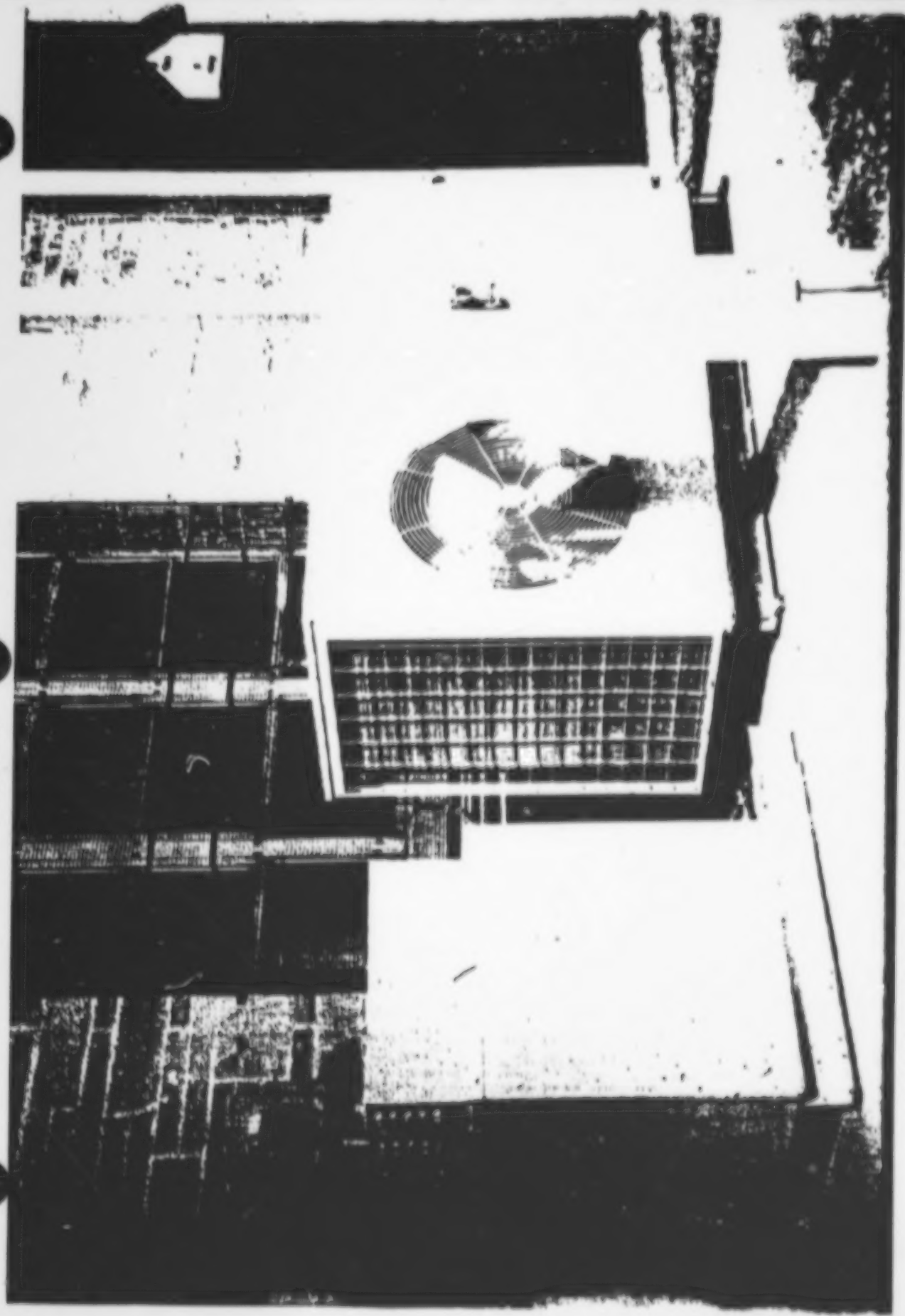


"Fuelmaster" Combination Gas/Electric Heat Pump

GHP FIELD TEST SITES



SLIDE 25



Aisin Seiki Prototype under Field Evaluation

SLIDE 26



SANYO PROTOTYPE OF VUILLEUMIER HEAT PUMP
(Courtesy of Tokyo Gas Co.)

DON ADKINSON
Adkinson and Associates

Biographical notes

Mr. Don Adkinson graduated from McMaster University in Hamilton, Ontario in honour physics at the Bachelor level and some time later with a Master of business administration degree.

After spending some 20 years in the concrete construction supply field, a new career was started in the late seventies when he became involved with solar technology.

In the early 1980's he helped establish the first production line of photovoltaic cells and modules in Canada at Solarcells Limited in Burlington, Ontario.

In 1981 he established ADKINSON AND ASSOCIATES. The firm has been involved in photovoltaic consulting activities, particularly in marketing and R and D fields.

Along with his work with the Canadian Standards Association, where he was chairman of the committee on photovoltaic modules F380, he has spent considerable time working with the International Community of Photovoltaic Standards through the International Electrotechnical Commission, Technical Committee 82, working groups 2 and 3. He is currently chairman of the Canadian subcommittee for TC's 82 on photovoltaic modules.

His work on photovoltaics has included extensive reports on performance monitoring of systems, water pumping applications, battery characteristics, and industry status reports. He is presently chairman of the C.P.I.A. and a former director of the Solar Energy Society of Canada. He is also a member of the Photovoltaic Technical Advisory Committee to Energy, Mines and Resources and a past chairman of that committee.

"Critical Assessment of the Canadian PV Technology."

DON ADKINSON

Adkinson and Associates

Paper abstract

This presentation summarizes a report that is being prepared by Energy Mines and Resources on the assessment of the photovoltaic technology in Canada. An overview of the photovoltaic technology is presented and an update of the global cost for PV modules and balance of system components to the year 2010 is projected for the Canadian context. Applications for photovoltaic energy are reviewed and some market projections are evaluated in light of these cost projections. The impact of photovoltaic energy with respect to energy, production, economics and environmental issues is discussed. Strategies for the future development of this technology in Canada are also presented.

PRESENTATION AT
ENERGY AND THE ENVIRONMENT CONFERENCE

HERATON CENTRE
MONTREAL, QUEBEC
MARCH 21, 1991

J. ADKINSON

CRITICAL ASSESSMENT REVIEW OF PHOTOVOLTAICS

VERHEAD

CRITICAL ASSESSMENT OF PV TECHNOLOGY

Purpose of paper

A presentation on photovoltaics is very appropriate at an Energy and the Environment Conference. Photovoltaics or PV for short has such appealing characteristics from an environmental point of view that it is almost an ideal form of electrical generation. What we wish to do in this paper is to hopefully provide an appreciation of this technology and its potential for creating a clean environment in the future. We will do this by addressing the following issues.

- Brief assessment of technology
- Why attractive and where used
- Environmental ramifications
- Who are the players
- Economics now and projections
- Market Projections

IDE

Background of the Critical Assessment

SUN.

This presentation is a summary of the findings of a report prepared by Energy, Mines and Resources, Canada for an internal review of the various renewable technologies. The report is entitled "PV Critical Assessment".

It is a report to review the state of the art in the PV industry, with a special emphasis on the Canadian sector and the impact on Canada's energy supply from now until the year 2010.

SL

What is Photovoltaics ?

PHOTOVOLTAICS

It is the technology of making electricity from sunlight by

means of a semi conductor device. We are all familiar with the warmth of the sun shining upon our skin as it produces heat, but the semi conductor device converts the sunlight not to heat, a thermal form of energy but into electricity, a high grade form of energy.

SL

PV EFFECT

To explain how it does this is beyond the scope of this paper. The electrical power produced by the device is in the form of direct current electricity with the voltage of the output dependent on the type of material in the conversion device which we normally call a cell.

SL

ROUND CELL, SQUARE CELL

Silicon cells come in round and square shapes and are joined together electrically to create an environmentally protected module.

SL

COMMERCIAL MODULES

The output of a PV device, such as a commercial module for charging 12 volt batteries, is described in terms of peak watts, which is the amount of electrical energy in terms of watts that would be produced under standard conditions which would be roughly noon hour on a bright sunny summer day. A typical commercial power module today has an output of about 60 peak watts, so that two of them together could power a 100 watt light bulb.

Another vital characteristic is that there is no inherent storage in the conversion device and hence the output must be used immediately as produced, or special provisions must be made to store the output in electro chemical form such as batteries, or in the form of delivered products such as pumped water or refrigerated cold.

You will recognise photovoltaic devices in solar watches and solar calculators and you have probably seen them on the satellites and space stations launched over the past ten years.

SL

PV END USE APPLICATIONS

There is a general breakdown of PV applications into 3 categories of space power, consumer power, and terrestrial power systems. As this gathering is focusing on the environment, we will direct our attention to the terrestrial power applications as these impact most directly on that environment.

2

EARLY TERRESTRIAL

These include both stand alone systems that are not hooked in any way to the main power grid and those grid connected systems which are intended to supplement the conventional grid power from the utility such as Hydro Quebec or Ontario Hydro.

SL

SYSTEMS & APPLICATIONS

The components of a photovoltaic power system include the following: array

- structure
- control
- storage
- auxiliary support
- power conditioner
- load

RND-02-011052

All of these are not necessarily found in every PV system as a simple configuration such as a water pump, could consist of only the array and the pump as the load.

Why is PV Attractive?

PV is attractive for many reasons. technically it is very reliable and can be configured to operate completely in an automatic mode. There is no fuel cost, and because there are no moving parts in the conversion system very little maintenance is required.

The PV conversion system is attractive environmentally because it is basically benign, with no noise, no fumes, no emissions and is really sustainable. There are no parts of the conversion cell that are consumed in the conversion process and the commercial product of today has a relatively long projected life..in the 20 year range. Another advantage is that it will work just about anywhere because the sunshine is universal and except for the extreme latitudes available everyday.

OH

SOLAR RESOURCES IN CANADA

Our Solar Resource in Canada is quite respectable and the annual mean solar radiation indicated on the chart makes PV applications possible in most Canadian locations.

OH

ANNUAL MEAN DAILY GLOBAL RADIATION

With all these good things going for this technology and if it is so good, one could easily ask "Why isn't every one using it everywhere?"

There are some disadvantages of course, the prime one being the capital cost of the systems for the initial investment. When comparing PV to conventional generation systems such as diesel generation with recurring fuel cost, a life cycle costing approach is necessary to provide a true comparison of the economics.

The sun produces a limited number of sunshine hours each day and they are not always when we need the electrical output, so that we have a requirement for energy storage. Our real problem is that we do not have a economical electrical storage technology today other than electrochemical batteries, which are not only expensive but heavy and cumbersome.

Where is it Being Used now?

Technically photovoltaic systems can power just about any load required. Practical considerations of economics and of space etc make the most popular applications currently, telecommunication systems, remote residential power, water pumping, village power, cathodic protection and specific market segments.

The Third World, of course is a most attractive area for PV applications due to the sunbelt locations and the lack of infrastructure for utility grids at the moment. Fifty percent of the Canadian activity in photovoltaics is identified as being connected to export sales.

OH INSTALLED PV CAPACITY 1990

The installed capacity in Canada in 1990 is estimated to be well over 800 kilowatts with the applications being broken down as on the chart. The lighting warning sector telling the greatest number is highly influenced by the Canadian Coast Guard's 3,200 systems that are powering their land based navigational aids all across Canada.

OH BIG TROUT INSTALLATION

Other Canadian installations, include this largest one in Canada at Big Trout, in North Western Ontario of approximately 10 kilowatts that is feeding a diesel grid for the small community.

OH WATER PUMPING

Domestic stock watering provides a means to keep the cattle out of the stream when drinking and thus reducing the

contamination of the ground water by their discharges.

HAZARD LIGHTS
Hazard warning lights for airport approaches are also very appropriate for PV.

SABLE ISLAND
On Sable Island where the wild horses are off the Eastern Coast of Canada, the Canadian Coast Guard has a larger PV system powering the East light, to provide a reliable and economical source of power.

BAXTER CENTRE
Near Ottawa a conservation area, known as the Baxter Centre utilizes a PV array for powering their orientation centre, for lighting etc.

LAPLACE RESIDENCE
This next installation is the residence of Ron LaPlace one of our C.P.I.A. Directors, who lives approximately 80 miles north of Edmonton at Colinton Alberta. He is completely independent of the power grid for his operations.

How can PV help the environment ?

There are at least 3 areas in which the photovoltaic technology can help the environment. First of all in the reduction of the CO₂ and other emissions from diesel generators. For every kilowatt hour of diesel generation displaced by PV .82 kg. of CO₂ is avoided.

Additionally in remote areas, primary batteries used to power various type of communication links etc are still littering the landscape where they have been dumped rather than having been flown out for proper disposal. Where PV is utilized instead of primary batteries the question of disposal becomes minimized.

The third area is in the reduction of noise. This you will appreciate if you have spent any time in a camp or lodge where electricity is produced by gas or diesel generator banging away through out the night.

PV systems operate without noise and from users, particularly those in the seasonal residence category report this as one of their most appreciated advantages of the PV Systems -Electricity with out noise.

HISPERIA 1MWp SYSTEM

The potential for PV as a significant contributor to the energy equation is illustrated by this 1 megawatt peak system at Hisperia in California. This is a demonstration system which feeds power directly to the high tension lines at a sub station and is displacing fossil fuel generated electricity in the southern California grid network.

PV today is also assisting the environment by providing power for the systems that monitor the various processes and the environmental conditions themselves.

Electric cars can be powered by photovoltaic produced electricity. It has been noted that running electric vehicles with power produced by fossil burning generation stations is somewhat self defeating. However if the power is generated by photovoltaics the environment receives no emissions, either from the source or from the vehicle itself.

An alternative to the electric vehicle for minimum emissions is the hydrogen powered vehicle and again if the hydrogen is produced through electrolysis with PV generated power a clean cycle is developed for the entire process. We are currently involved in a project with The Electrolyser Corporation of Etobicoke (near Toronto) to provide a PV/Hydrogen source for a project in California that will power hydrogen vehicles by the middle of this year.

Who are the Players ?

Who then are the players in the photovoltaic technology area?

We have system houses, distributors and retailers as well as manufacturers through out Canada who are currently marketing PV components on a day to day basis. These are listed in a publication called "The Canadian PV Source List" available from the C.P.I.A. or E.W. and R.

We have as well an R & D element in the Universities who are doing the basic and advanced research on new PV technologies.

CANADIAN PV ENERGY PROGRAM

Presently the ENER budget is in the neighbourhood of \$600,000.00 per year. It is expected that the creation of the

Energy Diversification Research Laboratory (EDRL) by Energy Mines and Resources at Varennes P.Q. will result in an increased budget to approximately one million dollars per year with 8 or more staff dedicated to photovoltaics.

EDRL SKETCH

This is an architects sketch of the new lab which will ultimately include the largest PV array in Canada, of around 100 kwatts peak.

Internationally, the U.S.A., Japan, Germany, France and Italy are the countries with the largest programs for the development of photovoltaics. The CEC is also quite active in the testing and development of photovoltaics in their lab at Ispra.

What is the Technical Status ?

Present commercial production modules convert approximately 10% of the solar energy into usable electric energy. This 10% efficiency results in an output for 1 square metre of module area of approximately 100 watts under high noon conditions. The modules are produced with well tested technologies and are warranted for 10 years or more.

The qualification tests to which the modules are subjected would indicate that a 20 year life time is a reasonable expectation for these products.

With concentration devices, efficiencies have been reported up to 37%, while silicon devices in the laboratory have reached about 23%.

When one compares these efficiencies to the overall oil to electric efficiency of rotating diesel generators, which are in the range of 20 to 25 % they compare very favourably.

SPECIFIC CHALLENGES 1. The specific challenges of the Canadian PV program include the development of inverters and controllers, storage systems, photovoltaic/thermal-electric generator hybrid systems, interfacing with grid systems, and development of Canadian standards and regulations. An additional challenge is looking at the potential of a PV manufacturing plant in Canada.

SPECIFIC CHALLENGES 2.
The challenges of the PV program include:

The development of market strategies for photovoltaic energy including tax credits, incentives, financing, demonstration projects and information and technology transfer.

Additionally international industrial cooperation to promote the use of Canadian PV technology in developing countries.

The final item is the assessment of the environmental and social cost for all the energy technologies to produce a fair comparison with PV.

What are the Economics today?

There are 2 ways of looking at photovoltaic systems costs. One is the cost per peak watt of the capital cost of the system and these are referred to generally as cost per peak watt.

PV SYSTEM COST PROJECTIONS

In these terms we see that the current cost of \$9.34 for 50kW system is projected to decrease to less than one third of that in the year 2010 to \$2.38. The central utility grid 1 megawatt system has an ultimate projected cost in the range of \$1.38 per Wp.

Because the low voltage low power residential systems have battery components and storage requirements the cost is obviously higher, but one can see that the decrease in cost will still be significant from the current \$10.55 figure to the year 2010 figure of \$5.47.

PV SYSTEM COST PROJECTIONS

The other measure of course is the cost per kWh of power produced and these figures indicate the current and projected costs projections in terms of kWh produced by the system.

For reference purposes the present utility price is shown as an average of .06 per kWh

When making comparisons however, it must be noted that in remote areas of the country where diesel fuel for generation is flown in, the power cost can range in excess of 50 cents per kWh today.

These projections are based on the current R & D programs that are in place in the U.S.A., Japan and Italy where significant funds are being committed to decreasing the production cost of the various components.

COST OF COMPONENTS

The projected decrease in the cost of the PV components is illustrated in this next table indicating an anticipated cost by the year 2010 of 42 cents per Wp per module. Inverters are the devices that convert the direct current electricity from the modules or from the PV storage batteries into alternating current or AC power and can be identical to the power delivered by the utilities power grid.

The BOS item on the last line refers to Balance of Systems, which includes the structure and the cabling to complete the system.

What are the Market Forecasts ?

Assuming the cost projections just seen come to reality, what type of growth can we expect to see?

PROJECTED GROWTH OF PV USE

Any projections, for 20 years hence are going to be subject to considerable uncertainty. However using the information available with regard to current systems these are the projected figures for the installed capacity of Canadian PV systems in the year 2010.

Residential power as you can see is the major application, with decentralized power being the second largest application.

PROJECTED PV CAPACITY

Translating these figures to a graph we can see the growth projections in the years to 2010, for a total capacity of well over 800 megawatts.

The study shows that photovoltaic energy will produce 250 gigawatt hours per year of grid electricity by the year 2010. This energy if displacing electricity produced in coal plants would eliminate 254 kilotonnes of CO₂, 8 kilotonnes of SO₂, and 700 tonnes of NOX, and 1 kilotonnes of VOX every year.

The displacement of electricity produced by diesel and gasoline generators in the same time frame should eliminate 164 kilotonnes of CO₂, 369 tonnes of SO₂, 120 tonnes of NOX, and 2 tonnes of VOX every year in that already fragile northern environment.

In addition, solid pollution from primary batteries will be eliminated by the production of 200 gigawatt hours per year from the primary battery sources.

How to get more information .

For further information on this technology and its' use or for the Source List of PV Equipment, I would refer you to:

The Canadian Photovoltaic Industries Association,
15 York Street, Suite 3, Ottawa.
Telephone 613 238 4041

or ~

EDR Lab of CANNAT,
210 - 2082 Blvd. Marie Victorin,
Varenes, Quebec.
Phone 514 852 4621.

EDRL PV PROGRAM

The EDRL Research PV program is designed to provide inhouse research and development facilities and the experience of a group of scientist, to help the Canadian PV Industries develop PV technologies.

EDRL OBJECTIVES

The objectives are:

- to establish the facilities to develop, test, and certify PV systems and components.
- to carry out technical evaluations and testing of new PV systems and components in new but promising applications such as:
 - remote power systems (stand alone and diesel hybrids)
 - transportation system - energy storage systems
 - production of hydrogen.
- develop performance and safety standards in conjunction with the appropriate agencies.
- establish a group of PV technical experts to provide technical support to the PV program

Photovoltaics is a fascinating and impressive technology. It is economic now in many applications, and with continuing lowered costs, has the potential for

significant contribution to the total energy requirements. At the same time it is very environmentally attractive and its use will contribute greatly to a more healthy and cleaner Canada. I hope you will promote its use wherever possible.

Keith Prater
Vice President, Technology

Keith Prater joined Ballard as a partner and Vice President R&D of Ballard Research Inc. in 1979.

Prior to joining Ballard, Dr. Prater was successively Assistant Professor of Chemistry, University of Texas at El Paso (UTEP), 1969; Associate Professor of Chemistry, UTEP, 1973; Director of Medical/Dental Professional Advising, UTEP, 1974; Adjunct Professor of Chemistry UTEP, 1979. In 1977 he was Director of Research for Ultra Energy Inc. and an associated company SBR Labs Inc.

With Ballard, Dr. Prater initially identified the stability of lithium dithionite as a discharge component of Li/SO₂ primary batteries. This identification led to the postulation of a rechargeable mechanism for this system. Subsequently, a \$15 million project with Amoco was developed to exploit this understanding by developing a rechargeable lithium battery. Dr. Prater led this development project and built a sophisticated research infrastructure and a team of 24 professional/technical staff.

Dr. Prater led the technical development into the allied fields of fuel cells and polymer chemistry. In 1988 Dr. Prater was elected President and CEO of Ballard Technologies Corporation from which position he successfully acquired the venture capital partners, Ventures West and the Federal Business Development Bank. When the fuel cells began to take on major market applications, Dr. Prater led the successful search for the present President and CEO, allowing the company the opportunity to grow into the product and market driven corporation envisioned as the future of Ballard.

Dr. Prater graduated from the University of Kansas, Lawrence, Kansas, in 1965 in chemistry and mathematics. He received a PhD from the University of Texas in 1969 in Analytical Chemistry. He was an NSF undergraduate research scholar, Mobil Oil Fellow and an Eastman Kodak Summer Fellow. He is a member of the American Chemical Society and the Electrochemical Society. Recently he has taken on responsibilities with the British Columbia Science Council Energy Sector Planning Committee and is Chairman of the Hydrogen Task Force. He is also a member of the Scientific Research Committee of the Hydrogen Industry Council.

Abstract

The Potential Market for Fuel Cell Technology in Canada

This presentation briefly describes the fuel cell as a generalized device and identifies the characteristics of the various fuel cell technologies which have developed. The fueling options for present and projected fuel cell systems will be discussed as will the potential applications. The opportunities for the Solid Polymer Fuel Cell, being developed by Ballard Power Systems, will be discussed in comparison with other fuel cell systems. Finally, demonstration projects underway or planned by Ballard will be described.

THE POTENTIAL MARKET FOR FUEL CELL TECHNOLOGY IN CANADA

**Mr. Keith Prater
Vice-President R&D**

Ballard Power System

March 20th-21st 1991

The Potential Market for Fuel Cell Technology in Canada

Introduction

The Industrial Revolution and the subsequent Transportation Revolution were powered by heat engines. The term "heat engine" includes the steam engine, the internal combustion engine, and the gas turbine engine. These devices rely on a multi-step process which begins with the combustion of a fuel to convert the energy in that fuel to heat. A small fraction of that heat is then converted into mechanical energy within the engine. The fraction of the heat which can possibly be converted into mechanical energy is limited by the amount of unused heat energy which is expelled to the environment in the exhaust.

The theoretical limitation on heat engine efficiency is determined by the so-called Carnot Cycle. For a steam engine, operating at 250°C, one cannot possibly convert more than 29% of the energy in the heated steam into mechanical energy. In a real system, thermal and frictional losses reduce the percentage further. A typical automobile operating in the city expels about 85% of the energy in the fuel it consumes into the environment as useless heat.

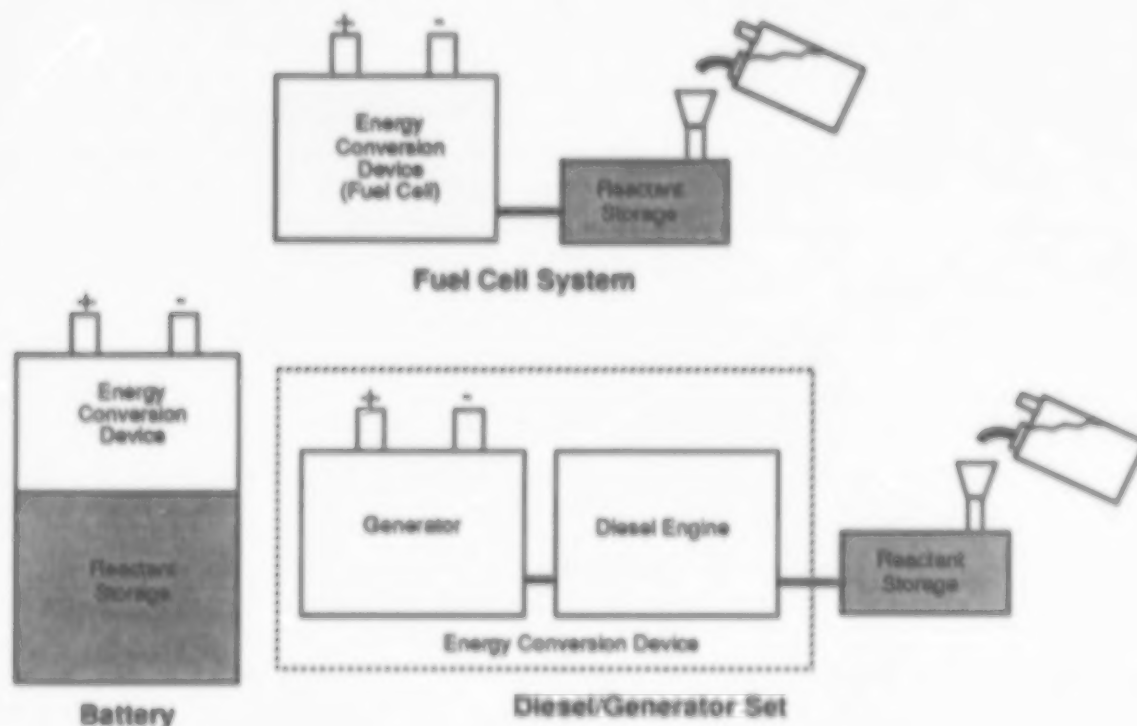
The fuel cell, by contrast, is a device which converts a fuel and an oxidant directly into electricity by an electrochemical process. The fuel is not burned to produce heat and the efficiency of energy conversion is not limited by the Carnot Cycle limits placed upon heat engines. The fuel cell, like a battery, has no moving parts in the energy conversion device, and thus suffers no frictional losses. Realistic energy efficiencies in excess of 50% can be achieved with fuel cell systems.

Though invented by Sir William Grove 150 years ago, the fuel cell found its first real application in the US space program of the 1960s. Since then, the fuel cell has evolved into five distinct fuel cell technologies, each with its own advantages and disadvantages for a particular application.

This presentation briefly describes the fuel cell as a generalized device and identifies the characteristics of the various fuel cell technologies which have developed. The fueling options for present and projected fuel cell systems will be discussed as will the potential applications. The opportunities for the Solid Polymer Fuel Cell, being developed by Ballard Power Systems, will be discussed in comparison with other fuel cell systems. Finally, demonstration projects underway or planned by Ballard will be described.

The Fuel Cell

Generically, the fuel cell can be best understood with reference to Figure 1, which schematically describes three energy conversion devices: the diesel/electric generator; the battery; and the fuel cell.



Diesel Generation/Battery/Fuel Cell Comparison
Figure 1

The diesel (or gasoline) generator produces electricity in a multi-step process. The energy in the fuel is first converted to heat by combustion. Heat energy is converted into rotary mechanical energy in the engine. Finally, the rotary mechanical energy is converted to DC or AC electrical energy by a generator.

As this is:

- a multi-step energy conversion process,
- a process based upon a heat engine, and
- a process involving moving parts and thus frictional losses,

it is an intrinsically inefficient method for producing electricity. Diesel generators typically have efficiencies in the range of 20 to 30%. Gasoline generators usually exhibit efficiencies in the 10 to 15% range.

Diesel and gasoline generators are also characterized by their high temperature of operation, their noise, their air pollution, and their requirement for regular maintenance. On the other hand, diesel and gasoline generators are inexpensive and readily available. They are also easily, even continuously, refuelable. The energy available from the generator is limited only by its supply of fuel.

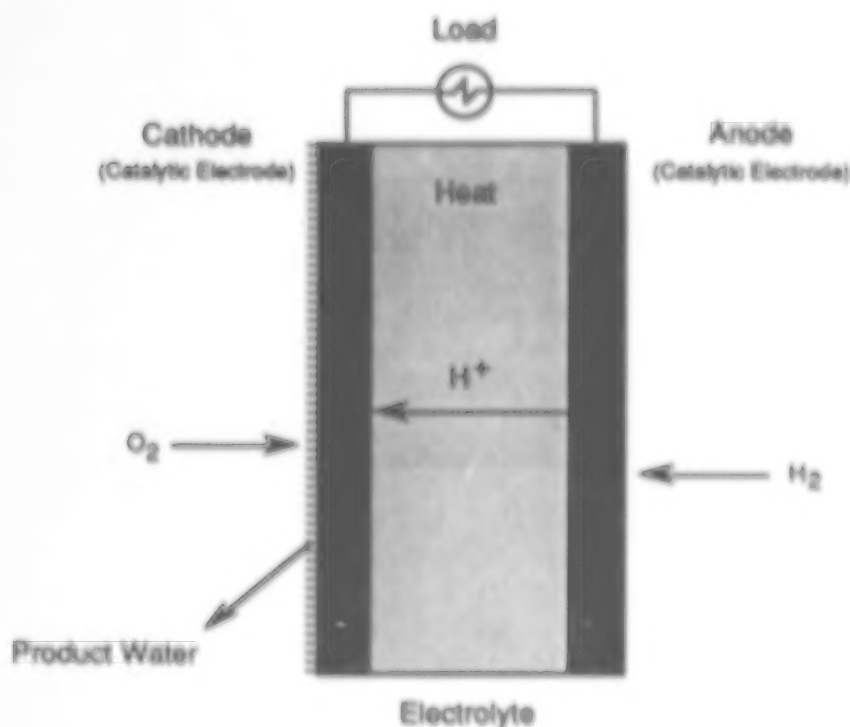
By comparison, the battery is an electrochemical energy conversion device. It converts the energy in the fuel directly into DC electricity. There is no combustion process, no multi-step energy conversion, and no frictional loss. The battery is intrinsically efficient, silent, non-polluting, and reliable. In most embodiments, the battery is also a low temperature device which produces power immediately on demand.

The battery suffers, however, in that all the fuel is contained within the battery case and is, therefore, limited. When a non-rechargeable (primary) battery has consumed its fuel, it is discarded and, with it, the energy conversion device and the "fuel tank". In a rechargeable (secondary) battery, one can reuse the energy conversion device and the "fuel tank", but one must wait for several hours for the recharging process to be complete. One cannot operate a battery continuously, as one can operate the diesel generator.

The fuel cell combines the advantages of both the diesel generator and the battery, while eliminating the major drawbacks of each. A fuel cell is essentially the electrochemical energy conversion device from the battery, engineered in such a way that it is continuously refuelable, like the diesel generator.

A fuel cell is intrinsically energy efficient, non-polluting, silent, and reliable. In some embodiments, it is a low temperature device which provides power instantly on demand, and exhibits a long operating life with minimal maintenance. Recent advances in Solid Polymer Fuel Cell technology have demonstrated substantial reductions in size and cost which now allow fuel cells to begin to compete in motive power applications.

A generalized fuel cell is shown in Figure 2. It consists of two porous electrodes at which the energy conversion process takes place. A fuel (hydrogen, in the case of the example) is supplied to one electrode while an oxidant, usually oxygen from the air, is supplied to the other electrode. At the fuel electrode (the anode) the fuel molecules give up electrons to the electrode and create an electric current in the wire leading from the fuel electrode through the electrical load to the oxidant electrode (the cathode). The remnants of the fuel molecules are now positively charged ions, hydrogen ions in the example shown in Figure 2.



Generalized Fuel Cell
Figure 2

The intrinsic tendency for the fuel and oxygen to react, as demonstrated by normal combustion, is manifested as a voltage between electrodes of the fuel cell. When the electrons, drawn by that voltage, arrive at the oxidant electrode, they are removed from the electrode by oxygen molecules, producing negatively charged oxygen ions. The build-up of positive ions at the anode and negative ions at the cathode would soon stop this process if there were no mechanism for these charges to be dissipated. There must, therefore, be an "electrolyte" between the two electrodes to allow the migration of ions from one electrode to the other.

In the example in Figure 2, the electrolyte allows the positively charged hydrogen ions to migrate from the anode to the cathode where they react with the negative oxygen ions to produce the product of this reaction, water. In this example, the electrolyte is an acid, completely analogous to the acid electrolyte in the automotive battery.

The electrolyte in a fuel cell must have three properties:

- it must be an electrical insulator, to prevent the short circuiting of the electric current;

- it must be gas impermeable, to prevent the direct mixing and combustion of the fuel and oxidant; and
- it must be a good conductor of ions, as this ion conduction completes the electrical circuit.

The choice of electrolyte defines the properties of a fuel cell. For this reason, fuel cell technologies are named by the nature of their electrolyte. Five fuel cell systems based on different electrolytes are in various stages of development. These electrolytes are:

- phosphoric acid (the Phosphoric Acid Fuel Cell or PAFC);
- an alkaline solution of potassium hydroxide in water (the Alkaline Fuel Cell or AFC);
- a molten carbonate salt (the Molten Carbonate Fuel Cell or MCFC);
- a solid oxide ion-conducting ceramic (the Solid Oxide Fuel Cell or SOFC); and
- a solid ion-conducting polymer (the Solid Polymer Fuel Cell or SPFC).

The characteristics of the present and proposed fuel cell systems based upon the five electrolytes listed above are presented in Table 1.

The fuel cell systems listed in Table 1, with the exception of the MCFC, consume hydrogen as their fuel. The MCFC can use both hydrogen and carbon monoxide as a fuel. Hydrogen can be produced by the electrolysis of water or by the catalytic reforming of a steam/hydrocarbon mixture. The most likely sources of hydrogen for fuel cell use are the steam reforming of natural gas (for stationary applications) or methanol (for mobile applications).

Reforming hydrocarbon fuels produces a gas mixture which contains hydrogen and a significant amount of carbon dioxide. That gas mixture is referred to as "reformat". With the exception of the alkaline fuel cell, which requires essentially pure hydrogen, all of the fuel cell systems listed in Table 1 can operate on reformat and, thus, on hydrocarbon fuels. The high temperature fuel cells (MCFC and SOFC) can, in principle, accomplish the fuel reforming process within the fuel cell itself, rather than requiring a separate device to accomplish this function. In practice, no fuel cell has yet operated using internal reforming.

	PAFC	AFC	SPFC	MCFC	SOFC
Electrolyte	H ₃ PO ₄	KOH/H ₂ O	Polymer	Molten Salt	Ceramic
Operating Temperature	190°C	80/200°C	80°C	650°C	1000°C
Fuels	H ₂ /Reformate	H ₂	H ₂ /Reformate	H ₂ /CO/ Reformate	H ₂ /Reformate
Reforming	External		External	External/ Internal?	External/ Internal?
Oxidant	O ₂ /Air	O ₂ /Air?	O ₂ /Air	CO ₂ , O ₂ /Air	O ₂ /Air
Efficiency	40-50%	40-50%	40-50%	>60%?	>60%?
Scale	200 kW to 10 MW	0.1 to 20 kW	0.1 kW to 10 MW	>100 MW	>100 MW
Applications	Small Utility	Aerospace	Motive/Small Utility	Utility	Utility

Fuel Cell Comparison
Table 1

Applications

Fuel cells technologies have been pursued principally in a search for a more efficient, non-polluting replacement for fossil fuel-burning utility power plants. The PAFC has been demonstrated in commercial applications in units ranging from 200 kW to 10 MW. The applications often involve the cogeneration of electricity and useful heat. In general, these systems are seen as being stand-alone systems which provide power and heat for a single building or a small group buildings. There is growing interest, particularly in Europe and Japan, in such distributed power systems. In some cases, the gas utilities are pushing the technology as a method of increasing market size. In other cases, the electric utilities are pursuing fuel cell systems as a means to reduce the need for large generating plants.

The electric utilities are also pursuing the high temperature fuel cell technologies as possible replacements for large central generating plants. The advantages of these systems would be a reduction in fuel cost, due to the higher efficiency of fuel cell systems, and a substantial reduction in pollution. These systems are still, however, several years away from meaningful, large scale demonstrations.

Capital cost has largely limited the introduction of fuel cells into utility applications. Today, the PAFC costs more that twice as much to install as a large

thermal power plant. On the other hand, the PAFPC cost is now approaching the cost of other small power plants and is beginning to find markets in areas which are particularly sensitive to air pollution.

In 1983 Ballard was awarded a contract by the Defence Research Establishment Ottawa (DREO) to develop a low cost Solid Polymer Fuel Cell capable of operating on reformed fuels such as methanol. Although DREO was the primary technical authority, the funding was supplied by Department of National Defence, National Research Council and Energy, Mines and Resources.

As a result of recent developments in SPFC technology at Ballard, the fuel cell is now being given serious consideration as a power source for motive applications. The Ballard SPFC is substantially smaller than other fuel cells and is approaching the power densities of internal combustion engines.

Ballard's work also offers the potential for substantial reductions in the cost of fuel cells. This should further speed the introduction of fuel cells into a number of markets, specifically, distributed power generation, stand-by power, and transportation.

Ballard Demonstration Programs

Ballard is presently involved in two programs to demonstrate the applicability of fuel cells to transportation needs. Ballard is the fuel cell subcontractor to General Motors for a US DOE program to demonstrate a methanol-fueled, SPFC-powered personal automobile within five years.

Ballard is the prime contractor in a project to demonstrate an SPFC-powered transit bus. The initial demonstration is to be completed within two years. This bus will be supplied with hydrogen stored on board the bus. If this approach proves out, the operation of a fleet of such buses would require a natural gas reformer at the bus depot to provide the hydrogen for each bus. The funding for this program is supplied by the BC Government and Energy, Mines and Resources.

Finally, Ballard is about to embark upon a project to demonstrate the use of the SPFC to provide utility power. Initially, Ballard plans to power its own building using natural gas as the fuel. This demonstration will be followed up with larger demonstration installations in several sites in Europe and North America.

Forecast

It appears that significant fuel cell installations will be in place by the turn of the century and that the applications will include both utility and motive uses.

RICHARD COTÉ

Notes biographiques

- Architecte depuis 1983
- Président et directeur de Ecosolaire Inc. entreprise de R&D en solarisation du bâtiment et en efficacité énergétique
- Président de l'Association Québec Solaire
- Membre fondateur de l'A.Q.M.E.

Biographical notes

- Architect since 1983
- President and Director of Ecosolaire Inc., an R & D company in the field of solar systems for buildings and energy efficiency
- President of the Québec Solaire association
- A founding member of the A.Q.M.E.

"The development of solar technology in buildings."

RICHARD COTÉ

Summary

A brief history of the use of solar technology in buildings will be followed by an analysis of the factors likely to increase the overall efficiency of solar architecture.

The final part of Mr Côté's presentation will deal with ways of bringing existing solar construction techniques into widespread use and developing new and more efficient concepts.

SOLAR ENERGY DEVELOPMENT FOR HEATING BUILDINGS

A-Richard Côté, Architect
Chairman, Quebec-Solar Association

This is an account of the principle solar techniques currently used in heating buildings. It includes an analysis of factors influencing performance and suggests ways to reach full potential.

For several decades, we have seen an upsurge in bioclimatic architecture, that is, design based on environmental impact; the clean energy provided by the sun's rays is becoming the natural choice for heating indoor spaces. Many noted architects, moreover, consider light a primordial ingredient in architecture.

Even in Roman times, the architect Vitruve recommended that main openings face south and that porticos be added to avoid overheating in summer. Closer to home, the Anasazi, an aboriginal people of the American southwest, more than 500 years ago built low-cost housing several stories high against south-facing cliffs to gain maximum benefit from the sun. The chronic shortage of wood which they faced was perhaps behind this ingenious solution.

A few decades ago, most of the principles governing solar architecture were developed in this same region. This time, the motivating factor was the oil crisis of the 1970s. The main craftsmen were the hundreds of individuals who decided to construct and test solar buildings, with the support of the American government and, particularly, the theories developed concurrently by the Los Alamos Scientific Laboratory.

This movement spread like wildfire in the late 70s, leading to a myriad of solutions adapted to countries as diverse as Scandinavia, France, Japan, Australia, Germany and Italy, to name but a few. Let us examine the methods used in all these buildings to profit from solar heating.

The basic phenomenon in the process is the greenhouse effect. Certain materials, such as glass, permit the passage of high frequency light rays but not low frequency heat rays. Light energy therefore penetrates readily through windows, to be converted into heat when it strikes opaque materials. A large part of it cannot escape, being reflected toward the inside by glazing or trapped in insulation material.

Three important operations which a solar building must ensure are:

- first of all, **capture**, which involves capturing the sun's rays. It is usually carried out through a south-facing facade or roof;
- then, **distribution**, which consists of sending the heat where it is needed. The most effective mechanism is radiation, but air convection and massive materials conduction are also used, particularly for the phase delay required between accumulation and discharge.
- finally, **storage**, which consists of accumulating heat produced when the sun is shining to use when it is not. This is done through a thermal mass inside the building.

It is the way these operations are combined with each other and with the other functions of the building which determines the type of approach used. First of all, there is what is known as **passive** solar architecture: this is the art of designing buildings so that the sun's rays are used to the maximum in terms of orientation, configuration, relation to the exterior and construction materials and methods. In addition, this provides brighter interiors and improves the quality of life. Passive techniques may be subdivided into direct or indirect methods.

With **direct gain**, the captor consists of south-facing windows which allow light to enter directly into the inhabited space. These openings may take the form of skylights on the roof where snow accumulation does not present a problem. An air collector may also be used on the south facade. Storage takes place in the thermal mass which is part of the surface of the room to be heated, for example, a concrete or ceramic tile floor, or walls of brick or stone. Distribution is through radiation: a ray of sunlight strikes the floor,

and is absorbed and transformed into heat. The warm floor in turn radiates the energy contained by the infrared wavelengths in all directions and it is absorbed by other surfaces until all surfaces reach the same temperature. During the night, the surfaces radiate toward the occupants, which creates a sensation of comfort even if the ambient temperature in the room is lower than the temperature of 20 degrees at which it is usually kept.

Elements essential for control are:

- good orientation
- an energy efficient building envelope, ie, well-insulated walls, roofs and floors and high-performance windows or insulating shutters to prevent the heat from escaping;
- eaves, awnings or plant screens to prevent the sun from penetrating too much when it is not required, for example in mid-summer or in late afternoon;
- natural ventilation to cool the mass during the night or discharge excess heat.

With **indirect gain**, the captor is a thermal mass placed between a window and the room to be heated. This mass absorbs heat on its exterior side during the day and gives it off toward the interior during the night, after a certain period of time which depends on the thickness and the nature of the material used. When the mass takes the form of a wall, it is known as a Trombe wall; when it is on the roof, it is called a roof pond.

The control system consists of insulating panels which are closed at night to lock in the heat and also, in the case of Trombe walls, valves which permit hot air convection into the room during the day and prevent the movement of air in the opposite direction during the night, which would cool down the room. These systems are attractive in dry, cold-winter climates, since they may also be used to cool the building in summer if the operating mode is reversed.

Distribution is mainly through radiation, but convection is also used during the day. Storage is directly in the mass. Water is often used, because its storage capacity is much greater than that of masonry for a given volume. The solarium is midway between these

two approaches. It works directly within its own space and semi-directly in adjoining rooms.

Finally, we have the **active** approach, usually a building element which serves specifically as a captor. It may be part of the south facade, the southern slope of the roof or completely separate from the building. It is a type of heat exchanger, the surface of which absorbs the sun's rays and transforms them into heat. This is somewhat the same principle as a black asphalt road which becomes very hot when the sun strikes it. The absorber of the photothermic converter, as it is called in scientific circles, may be isolated from the ambient milieu using a vacuum tube or a sheet of glass or plastic, or by nothing at all in the case of certain captors used only in hot weather. A liquid, such as water or antifreeze, or air is circulated through tubing to remove heat from the captor and take it where it is to be used. The heat may be used immediately, for example in the case of a **solar wall**, as on some industrial buildings such as the Ford Company plants at Oakville, Ontario and at various locations in the United States. These captors are used solely to preheat ventilating air.

Heat may also be stored for later use. Storage may be in a concrete floor slab, as, for example, in a **direct solar floor**, or in a water tank or phase change material, as, for example, in an **integrated solar facade**, or in a bed of stone under the floor or pipes buried in the soil. Distribution is through radiation if the thermal mass is adjacent to the room to be heated or by convection if storage is further away. When natural convection (thermosyphon) is used as a motor to circulate the liquid, the system is considered strictly passive.

A good solar building usually combines all these approaches, optimized for a very specific climate and situation. There are scientific rules for calculating the proportion of glass in relation to the thermal mass, the dimension of roof cornices and fluctuations in temperature for a given climate.

The solution best suited to our northern climate and average amount of sunlight should combine strategies for the short, medium and long term. The **daily cycle** calls for a thermal mass of an optimal thinness and specific heat associated with high-performance glazing proportional to the amount of sunlight. Mechanisms for nighttime occlusion of windows, which have long been a weak point in the thermal envelope, also need to be developed. Solar contribution of 30% to 40% of heating needs may be expected with the ordinary and inexpensive techniques used in these passive elements. The **annual cycle** calls for specific capture, reduced-volume phase change storage and mechanical distribution systems. We can anticipate doubling solar gain once interseasonal storage is perfected. This problem should be an R&D priority for the coming years.

Since very little applied research has been carried out on solar energy in Quebec, calculation rules and construction systems geared to our climate and traditional construction methods have yet to be developed. This requires an effective partnership of researchers, builders, government, etc.

The main problem preventing greater use of passive solar heating is that the public, business and decision-makers are not up to date on the relatively simple techniques required, or they are not prepared to pay the slightly higher cost of better quality construction. Mechanisms must be introduced to bring these groups up to date and keep them informed. In addition, tax incentives or financial instruments must be created to help consumers invest in integrated energy producing equipment for their buildings, as Hydro Quebec has done.

Another priority area is the legal field. At present, no legislation guarantees a consumer access to the solar resources of his land. On the contrary, poor street orientation and municipal by-laws often prevent buildings from taking advantage of the sun.

The EEC recently implemented an important solar R&D program on collective housing and office buildings, indicative of the importance given elsewhere to what will likely be our main source of energy for the next century. Many techniques using this form of energy already exist, and it is therefore urgent that information on solar construction be adapted for and disseminated to the public and construction professionals. It is also essential to intensify research and development in this area to make existing solutions more affordable and develop higher performance systems. This small investment today in solar energy will provide innumerable dividends for our descendants tomorrow.

This means that forest biomass research is aimed at developing new procedures for processing and exploiting forest residue, with emphasis on technologies for fractionation of the biomass. Planned products include: low yield papermaking pulp, fine chemical products derived from lignin extracts, adhesives made from lignin, special fibreboard and cogenerated electrical and thermal energy.

The role of CQVB

A transfer and community leadership organization, CQVB disseminates information by making it part of the transfer process, and through its role in co-ordinating research consortia.

During its first mandate (1985-1991), CQVB invested \$2.3 million in the field of forest biomass research, or 30% of its R&D budget. This investment generated \$4.2 million in outside contributions, or 24% of total outside R&D contributions, and in January 1991, 21 forest sector projects had been completed or were underway.

Background

Owing to both its energy potential and the environmental problems it poses, forest residue in Quebec is, like urban waste, a resource which cannot be overlooked when it comes to energy management.

Size of the forest biomass

The increasingly stringent standards of the Quebec Department of the Environment and the implementation of Bill 150, the new act regulating public forest activities, make wood residue, from the forest to the plant, a matter of ever more pressing concern. According to Quebec Department of Energy and Resources statistics, forests are being harvested at an annual rate of 32 million cubic metres. The pulp and paper and lumber industries generate a yearly average of 4.15 million TMA of logging residue in cutting and silviculture treatment areas, and 3.3 million TMA of barking residue and sawdust in the timber yards of sawmills and pulp and paper plants. To this may be added the 170,000 tons of sludge produced by pulping units.

Problem

These figures illustrate both the environmental and economic problems of the disposal and exploitation of residual wood fibre. These two problems in turn rest upon a more fundamental and equally pressing issue, that of the availability of **persons with innovative research and development ideas** to solve them.

In broad terms, solutions to the problem of forest residue are closely linked to the value which can be added to this waste and which, in the current energy context, must go beyond energy alone. The biomass must be seen as a resource for the replacement of hydrocarbons in the petro-chemical, as well as the energy field.

Biographical Notes

CHRISTIAN OUELLET

Christian Ouellet is an architect who has more than thirty five years of experience including a decade of full time professor at Montreal University. He received his master degree in building from Manchester University in 1974. Since then, he has been involved in alternative energy and energy efficiency in buildings ie. integration of passive solar in all types of buildings.

His architectural practice is based on the quality of life at work and at home. Christian Ouellet has been the founder of GRACE Institute from 1983 till 1990. He was an executive member of the Association québécoise de la maîtrise de l'énergie and vice-president of the Association Québec Solaire. He is now one of the directors of Forum Energie Centre-Ville and vice-president of the Solar Energy Society of Canada Incorporated.

PIERRE GAUTHIER

Notes biographiques

Monsieur Gauthier a obtenu son diplôme d'Ingénieur Mécanique en 1977 de l'École Polytechnique de Montréal.

Il a débuté sa carrière au sein de Gulf Canada Ltd, où il a oeuvré pendant neuf ans à différents niveaux de l'entreprise notamment, en Ventes, en Planification et en Administration.

Il s'est joint à Gaz Métropolitain, Inc. en 1985 à titre de Directeur, Développement et Transfert technologique. Il est présentement Directeur du groupe DATECH, division qu'il a créée en 1986, Président de NERGITEC inc., une entreprise de transferts technologiques ayant comme partenaire le Gaz de France, de même que vice-président de CONSULGAZ inc., une société à part entière d'ingénierie et de consultation technologique.

Monsieur Gauthier est très actif dans le domaine de la recherche au niveau des technologies gazières, particulièrement auprès de divers comités dont l'Association Canadienne du Gaz, l'Association Américaine du Gaz, le Conseil de l'Hydrogène et le Conférence Board du Canada.

Biographical notes

Mr Gauthier graduated from Montreal's Ecole Polytechnique with a degree in mechanical engineering in 1977.

He started off at Gulf Canada Ltd and worked there for nine years in various capacities, notably in Sales, Planning and Administration.

He joined Gaz Métropolitain Inc in 1985 as Director, Development and Technological Transfer. He is now Director of Groupe DATECH, a division he created in 1986, President of NERGITEC Inc, a technological transfer firm working in partnership with Gaz de France, and Vice-President of CONSULGAZ Inc, an engineering and technological consulting firm.

Mr Gauthier is very active in gas technology research, particularly with various committees, including the Canadian Gas Association, the American Gas Association, the Hydrogen Industry Council and the Conference Board of Canada.

"Cogeneration: Application of gas turbines in industry."

PIERRE GAUTHIER

Paper abstract

Although cogeneration has existed in North America for the past 85 years, its development in industry, particularly with natural gas turbines, is much more recent.

This talk about that application will cover the different types of cogenerating equipment, including steam turbines, and more particularly, gas turbines and generators, and the different uses in industrial processes.

Some operational and financial considerations will be touched on regarding the use of cogeneration by industry and its environmental impact.

COGENERATION
APPLICATION OF GAS TURBINES IN INDUSTRY

DELIVERED ON MARCH 21, 1991

ENERGY AND THE ENVIRONMENT

By: Pierre Gauthier
Director of Groupe Datech

With special assistance from:
Roland Francoeur, Eng.
Senior Advisor,
Gaz Métropolitain Inc

2

Ladies and Gentlemen:

I am pleased to have been invited by the conference organizers to give a talk on cogeneration.

I. INTRODUCTION

"Cogeneration" is a relatively new term in the technical vocabulary. It simply means the use of a primary source of energy to generate two forms of energy, in other words, the opposite of bi-energy.

The two forms of energy generated are motive power and thermal power. A cogeneration system usually uses an engine to generate motive power to drive a generator and recover heat generated by the engine to produce steam, hot water or hot air which can be reused in a process or in a heating or air-conditioning system.

The use of power in series is what distinguishes a cogeneration system from a thermal power station.

The most widely known cogeneration system is the automobile. It burns gasoline to produce the motive power that drives the vehicle and generates the electricity required by the vehicle and also to produce heat to warm passengers in winter.

Cogeneration systems have existed in North America for over 85 years. However, energy costs, regulation and interconnections with distribution networks have played a large role in the fairly rapid development of cogeneration as an alternative power service.

Today, most new cogeneration systems are large and designed for specific facilities. They are thus systems primarily adapted for big industrial clients.

There are also commercial and institutional type cogeneration systems. Compact, standardized systems are being developed for the market of hospitals, hotels, laundries and other institutions, in short any application requiring heat and electricity that is suited to cogeneration.

This could be a good technical/economic solution for new buildings or additions. We will now look at the different systems available, their characteristics, some typical applications and incentive factors that could allow them to be installed in certain specific sectors.

II. DESCRIPTION

Cogeneration involves the reuse of thermal power rejected by the engines for another application. The use of power in series is

what distinguishes cogeneration systems from conventional thermal power stations and makes it possible to achieve the high outputs obtained through cogeneration.

Except for special technologies such as fuel cells, cogeneration systems involve an engine driving a generator. Typically, the desired power of the system dictates the type of engine to be used. Generally, they can be rated as follows:

Rating Table

<u>Type of Engine</u>	<u>System Rating</u>
reciprocal engines	under 1,000 kW
gas turbine	from 3,000 to 10,000 kW
steam turbine	over 10,000 kW

Systems under 1,000 kW use reciprocal engines because of their better efficiency and lower cost for this range of power, while gas turbines are preferred for systems from 3 MW to 10 MW because of their small size and lower cost, and for systems over 10 MW, steam turbines take up most of the market.

Other technologies are suitable for use in cogeneration. One of the most promising is that of fuel cells. A great deal of research is being done in this field since these cells have the potential for high conversion efficiency with minimal maintenance costs.

We will now take a more detailed look at gas turbines and steam turbines since they can be used in combination, as well as the components of a cogeneration systems.

III. TECHNOLOGICAL CHARACTERISTICS OF FACILITIES

All engine manufacturers give their energy requirement specifications in net calorific value (PCI), whereas in the gas industry we always talk of gross calorific value (PCS), and for a very specific m^3 . The difference is approximately 10%. In this talk, I will use PCI.

Continuous power applies when the engine-generator unit is the primary source of power. In this case, the power selected is intended for continuous operation that will ensure long life for the facilities with minimum maintenance. That is what is used in selecting cogeneration systems.

Standby power applies when the engine-generator unit is used as a backup power supply. This power applies 24 hours a day for the duration of the primary power problem.

Temporary power is that which the engine-generator unit can supply for a short period of time, typically from 2 to 24 hours.

A. Gas turbines

The operating principle of the gas turbine consists in using a primary fuel such as natural gas, burning it in the combustion chamber and decompressing the products of combustion in a turbine to generate mechanical energy.

There are two types of gas turbines:

- . industrial gas turbines;
- . turbines derived from turbojets.

Industrial gas turbines have a single shaft, several combustion chambers and are generally of greater power.

Turbines derived from turbojets have one combustion chamber and two stages leading to the multistage axial-flow compressor.

Combustion products are then directed to another use or are converted into another form of energy.

There are a number of possibilities:

- . direct use in a drying process;
- . production of steam and/or hot water for heating purposes;
- . production of steam for an absorption air-conditioning unit;
- . direct use of combustion products for heating and/or air conditioning.

1. Drying process

A gas turbine can be used to drive a generator to produce electricity, while at the same time combustion products are used directly in a drying process.

This system is very efficient; more than 95% of the energy is found in the form of electrical power or in the form of heat used for drying purposes. Typical applications are drying wood, brick or grain and in laundries.

2. Heating

Another possibility is for combustion products to be used to produce steam or hot water. This is the most common and widespread application. The steam is then used in a process or to heat the building.

3. Air conditioning

A third possibility is for steam or hot water to be used not only for heating purposes but also in an absorption system used for air conditioning.

4. Heating and air conditioning

A fourth possibility is for combustion products to be used directly in an Hitachi type absorption system, for example, to produce cooling water and/or heat.

In the last three possibilities, the overall efficiency of these systems is approximately 80%.

A gas turbine can require a fairly high gas pressure. For example, the combustion chamber of the Garret 831 turbine requires 140 lbs/in², and to compensate for losses in the piping, controls, filters and injector, the manufacturer specifies 200 lbs/in² as required pressure.

Depending on the gas pressure available, this compressor can require from 25 to 80 kW of power and cost from \$50,000 to \$90,000. It is thus a factor that must be taken into consideration.

B. Steam turbines

In a steam turbine system, the primary fuel is burnt in a boiler to produce high-pressure steam. This steam is directed toward a steam turbine and its decompression in the turbine generates mechanical energy which is used to generate electricity by means of a generator. In some cases, low-pressure steam can be used for heating or air conditioning.

There are two main types of steam turbines: condensing turbines and back-pressure turbines.

1. Condensing turbines

In a condensing turbine, all the steam enters the turbine at a specific constant pressure and after decompression the steam exhausts from the turbine at a pressure less than atmospheric pressure.

2. Back-pressure turbines

In a back-pressure turbine, all the steam enters the turbine at a specific constant pressure and after decompression exhausts from the turbine at a pressure above atmospheric pressure.

This steam is then reused for other thermal needs in the plant.

When high-pressure steam is produced in a thermal power station and thermal needs require only low-pressure steam, the use of a back-pressure steam turbine instead of a pressure reduction valve is unbeatable. The required investment is low and output high.

In some cases, it is even possible to increase the pressure of steam produced in an existing boiler so as to increase the power and efficiency of the turbine, at a minimal cost.

The only drawback is that the back-pressure steam turbine generates little electrical power per pound of steam decompressed in the turbine. In a typical facility, a back-pressure steam turbine will produce 40 kWh per million Btu of steam, while a condensing steam turbine or gas turbine can produce much more.

Power can be increased by lowering the exhaust pressure, with the limit being a condensing turbine, but in that case it is no longer a cogeneration system.

C. Combined cycle

The use of gas turbines and steam turbines can be combined to generate more power, in which case stack gases from the gas turbine are recovered by means of a boiler with or without post-combustion producing high-pressure steam to drive a condensing or back-pressure turbine. The choice of the steam turbine depends on the electrical power requirements and steam requirements for the process.

To use this cycle, the steam produced by the cogeneration system must be greater than plant needs where steam and electrical power needs vary considerably.

D. Generators

Two types of generators are used in cogeneration systems: induction generators and synchronous generators.

1. Induction generators

To be able to operate, an induction generator requires an external reactive electrical power source to activate its magnetic field. It is the least costly to hook up to the electrical system.

2. Synchronous generators

A synchronous generator generates all electrical power required for its magnetic field. It can therefore operate without being hooked up to the electrical system but requires a frequency monitor. This type of generator is used in standby systems.

Both types of generators cost approximately the same. However, if one adds the cost of the synchronization system, induction generators become the logical choice for small facilities.

3. Power and power factor

Generators are usually specified for a certain power and a certain power factor. If the user tries to operate the generator at its rated power and a lower power factor, it will overheat.

IV. SITE CHARACTERISTICS

A. Operational considerations

To ensure the economic viability of a cogeneration system in the commercial sector, it is very important that recovered thermal power be used. In this sector, recovered thermal power is primarily used for producing hot water, heating and air conditioning.

A second consideration is that the electrical demand and thermal demand should remain relatively constant over time and coincide as much as possible.

A third important point is that installation costs can be minimized by centralizing heating and cooling systems and systems that produce hot water.

In a typical cogeneration facility, thermal power is transmitted to the heating or air-conditioning system loop by means of a heat exchanger installed upstream from the existing air conditioning or boilers. In this way, the system can respond to thermostats as required.

B. Other considerations

The most profitable cogeneration systems are those that operate at a high power and have a good utilization factor. Applications

that require a constant thermal load and electrical demand present the best potential for a cogeneration system. The systems must therefore be designed for the client's minimum thermal loads in order to maximize profitability.

However, since electricity rates are generally much higher in the commercial sector, this is a factor that favours cogeneration.

Natural gas has many advantages over other fuels in cogeneration systems, including high efficiency in generating electrical and thermal power, ease of handling, no storage, less maintenance and longer equipment life. It can also comply with environmental restrictions much more readily than other fuels.

V. FINANCIAL COMPARISONS

Until recently, cogeneration systems were used mainly in the industrial sector. However, R&D, especially in the United States, is gradually introducing this technology to the commercial sector.

Cogeneration does not always generate heat and motive power at the lowest cost. In places like Quebec, the cost of electrical power is so low that cogeneration is justified only in certain applications or for certain types of clients. When there is a good correspondence between electrical demand and heat demand, cogeneration could be a possibility.

VI. INCENTIVE FACTORS

A. Positive factors in the United States

One piece of legislation that facilitates the introduction of cogeneration in the United States is the PURPA (*Public Utilities Regulatory Policies Act*), which was designed to encourage cogeneration.

This law stipulates that, under certain conditions, electric utility companies must buy surplus power from cogeneration systems and must also supply additional or backup electricity required by cogenerators at a fair and reasonable cost.

This last stipulation is especially interesting in that it eliminates the cost of installing standby generators and does not require that all the client's electrical power requirements be supplied.

B. Profitability criteria in Quebec

- lower purchase cost for system;
- installation cost kept to a minimum;
- reasonable maintenance costs;
- introduction of incentive programs;
- additional incentive factors:
 - access to electrical network for backup service at a reasonable cost,
 - reliability of systems with manufacturers' guarantees,
 - good after-sales service,
 - easy installation and operation,
 - possibility of buying back surplus power at a reasonable cost.

VII. ENVIRONMENT

The use of natural gas as a fuel and the combustion efficiency of the turbine can result in emissions that more than meet government standards. SO₂ emissions resulting from the combustion of natural gas are considered nil, and NO_x emissions produced by natural gas during combustion are 20% less than those emitted by the combustion of other hydrocarbons. Moreover, certain techniques such as injecting steam into the combustion chamber can be used to reduce NO_x emissions by 80%.

Based on samples from the Cascades cogeneration system at Kingsey Falls, it was determined that emissions of nitrogen oxides (NO_x) and particles were respectively 20 and 100 times below environmental standards.

CONCLUSION

Cogeneration systems for generating electricity and heat are not new; they have been used in the United States and Canada since the beginning of the century. However, the recent economic situation has given new impetus to this form of power production, and future developments will certainly permit greater and greater penetration of this technology, even in traditional electrical power markets.

Gas turbines are efficient and compact and are a technological option that can generate a high level of thermal power compared to engines.

Cogeneration systems can be as easily installed in a renovated facility as in a new one. There is no technical difficulty in either case.

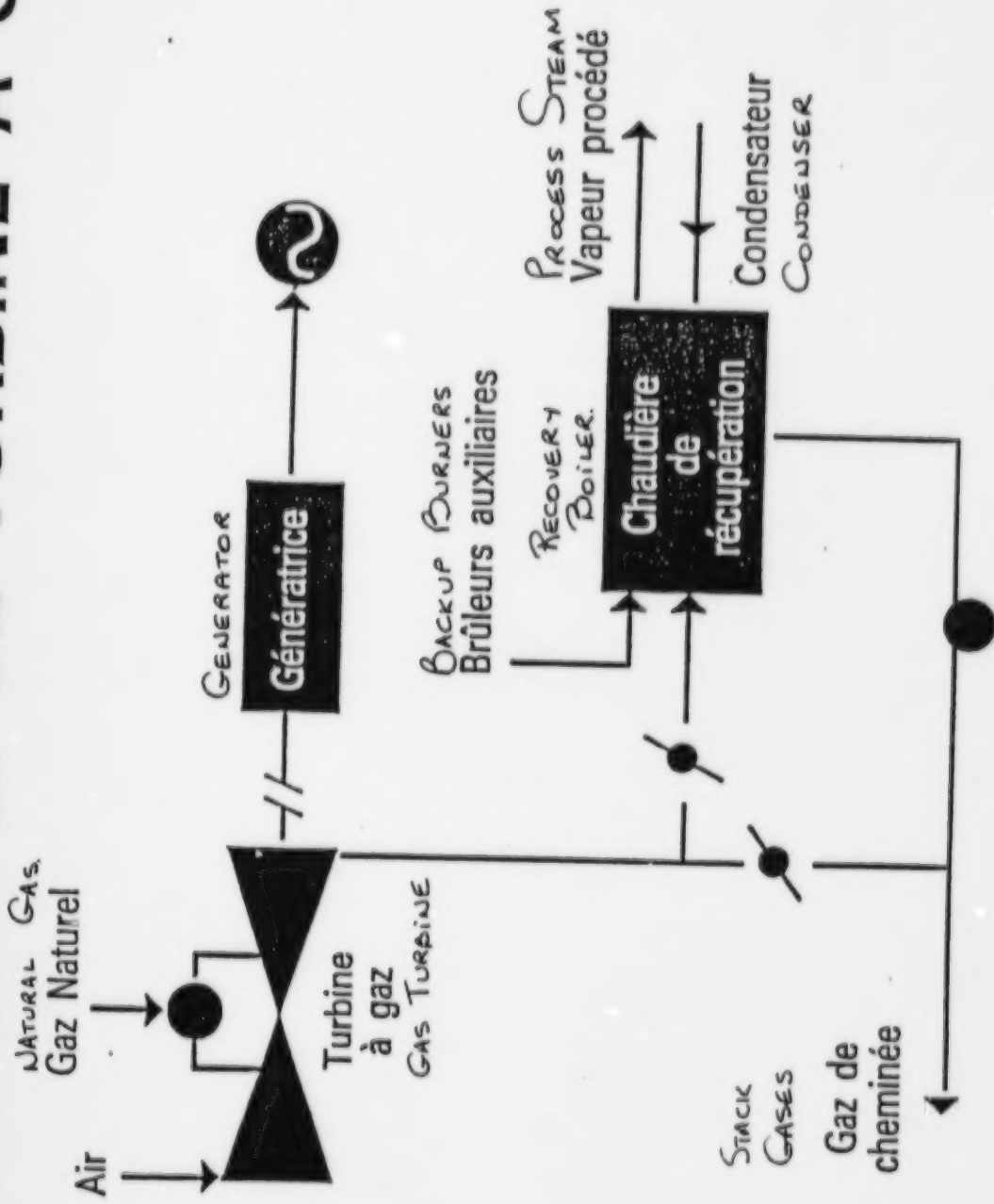
Profitability depends on the following factors:

- investment costs;
- ratio between electrical demand and thermal demand;
- ratio between the cost of electricity and the cost of natural gas;
- service and maintenance costs.

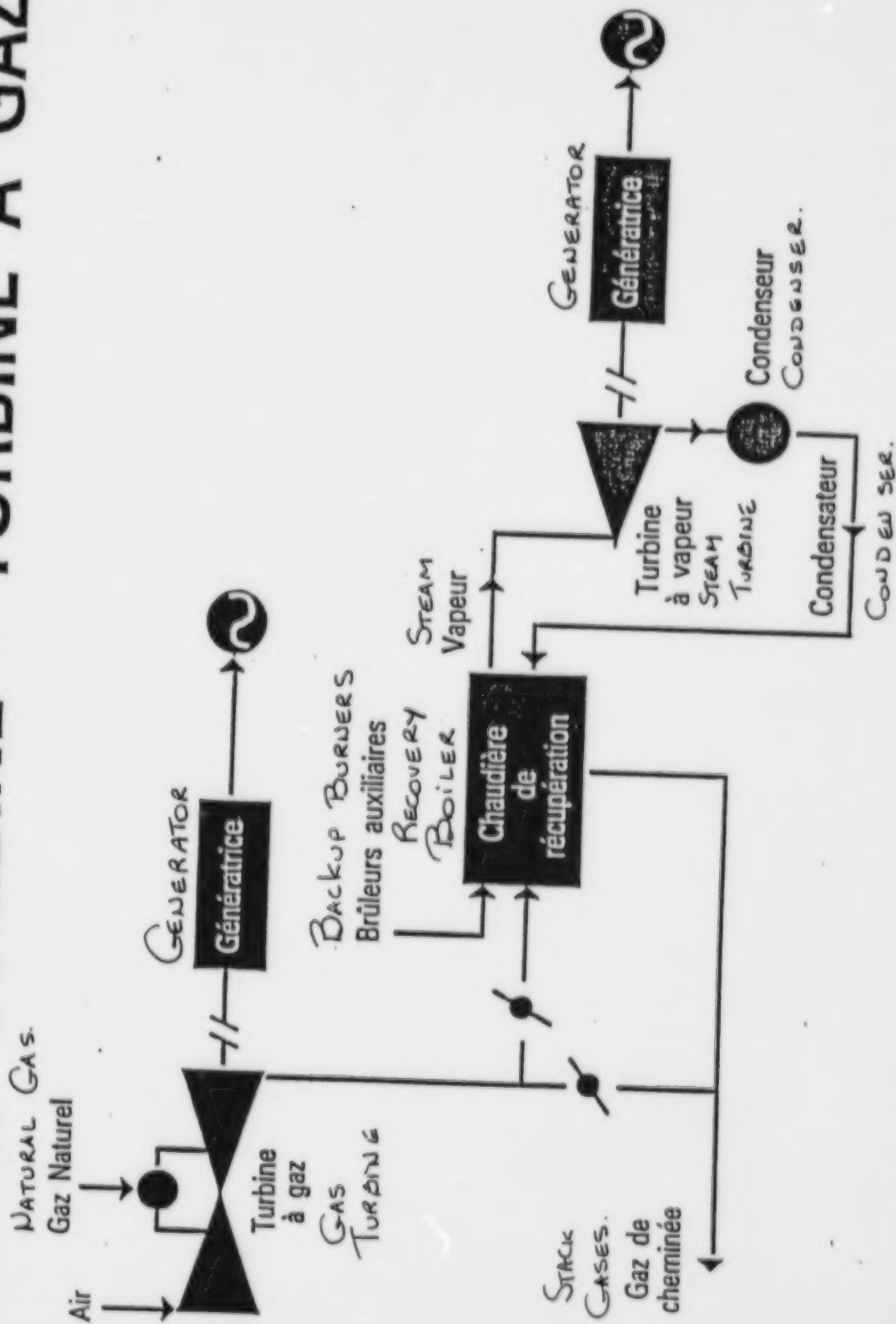
The key to success for cogeneration lies primarily in reducing investment costs by developing factory preassembled modular systems in order to minimize design and assembly time and in the introduction of incentive programs.

SINGLE-CYCLE GAS TURBINE

CYCLE SIMPLE DE TURBINE À GAZ



COMBINED-CYCLE GAS TURBINE CYCLE COMBINÉ - TURBINE À GAZ



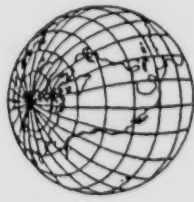
COMPARATIVE TABLE
OF INVESTMENT COSTS
ACCORDING TO INSTALLED CAPACITY AND TYPE OF COGENERATION

CAPACITY	CYCLE	UNIT COST
20 MW	Single	\$1,200/kW
50 MW	Single	\$ 800/kW
50 MW	Combined	\$ 950/kW
100 MW	Combined	\$ 650/kW

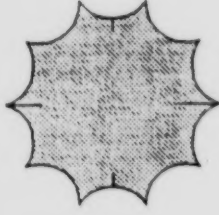
COMPARATIVE TABLE¹
EFFICIENCY AND EMISSIONS - NATURAL GAS VERSUS OIL

	EFFICIENCY	EMISSIONS (kg/MWh)		
	%	SO ₂	NOx	SO ₂ + NOx
<u>COGENERATION</u>				
- Single cycle - natural gas	75	0	0.23	0.25
- Single cycle - No.2 oil	75	0.01	0.47	0.49
- Combined cycle - natural gas	43	0	0.41	0.41
- Combined cycle - No.2 oil	42	1.18	0.91	2.09

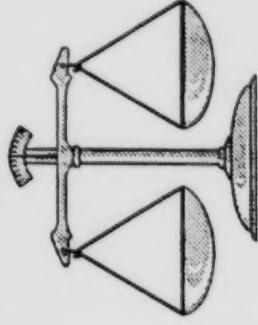
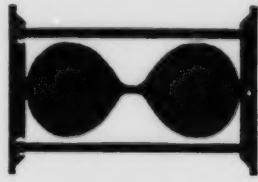
¹ Natural gas use for pollution control, Gas Research Institute



Renewable Energy
into the 21st Century:



Towards A
Sustainable Development Strategy



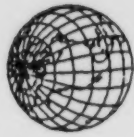
Jay C. Barclay
Office of Environmental Affairs
March 21, 1991

Evolving Energy Policy Context

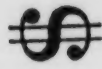
- Oil Dependence
- Oil Market Price Shocks
- Supply Diversity
- Market Orientation
- Sustainable Development

SUSTAINABLE DEVELOPMENT

The 3 E's - Key Components



ENVIRONMENT



ECONOMY



EQUITY

SUSTAINABLE DEVELOPMENT

Brundtland Commission Definition:

"Development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs"

Present patterns of energy production and use are **not** sustainable

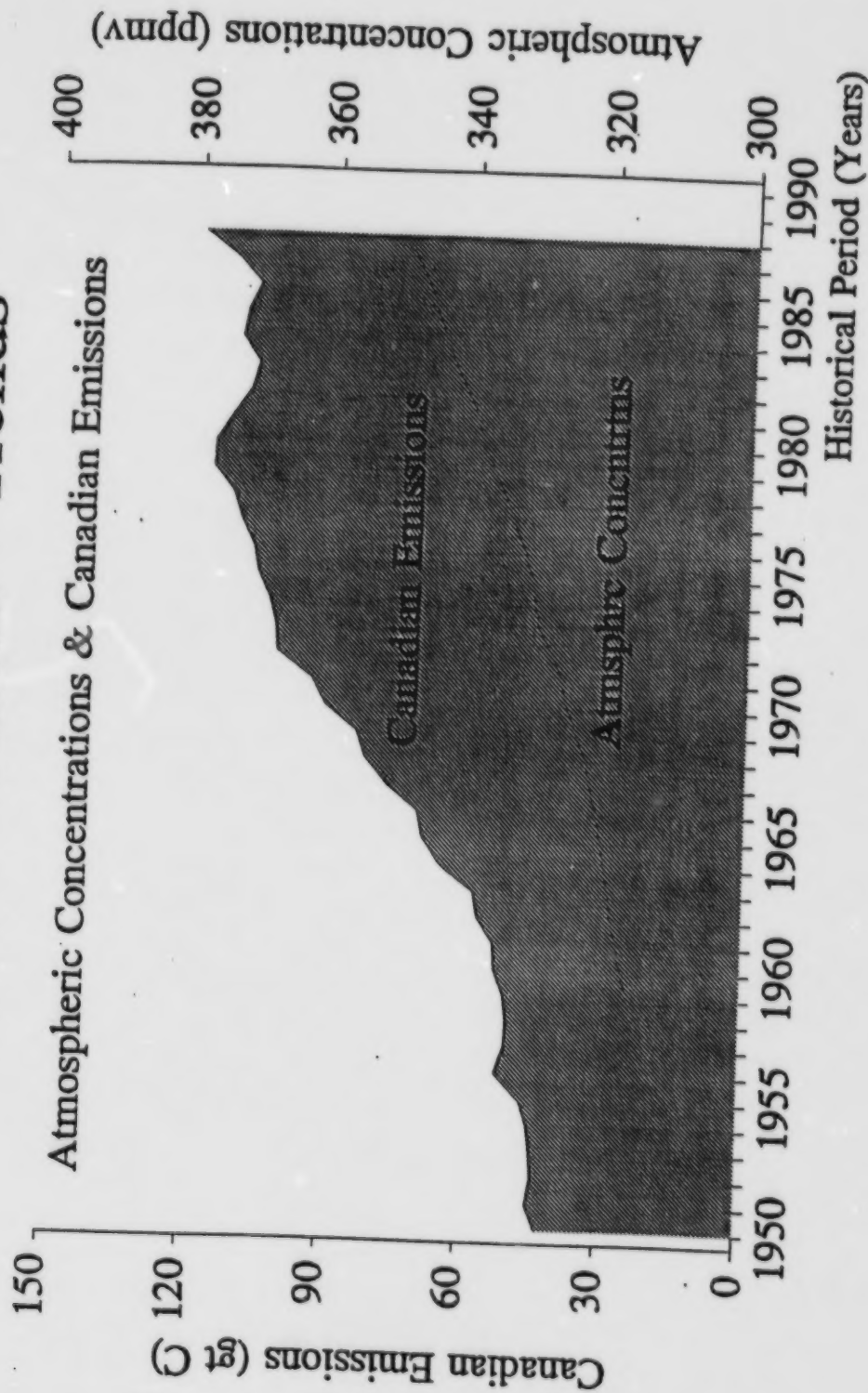
KEY ENVIRONMENTAL ISSUE:

- Global Climate Change

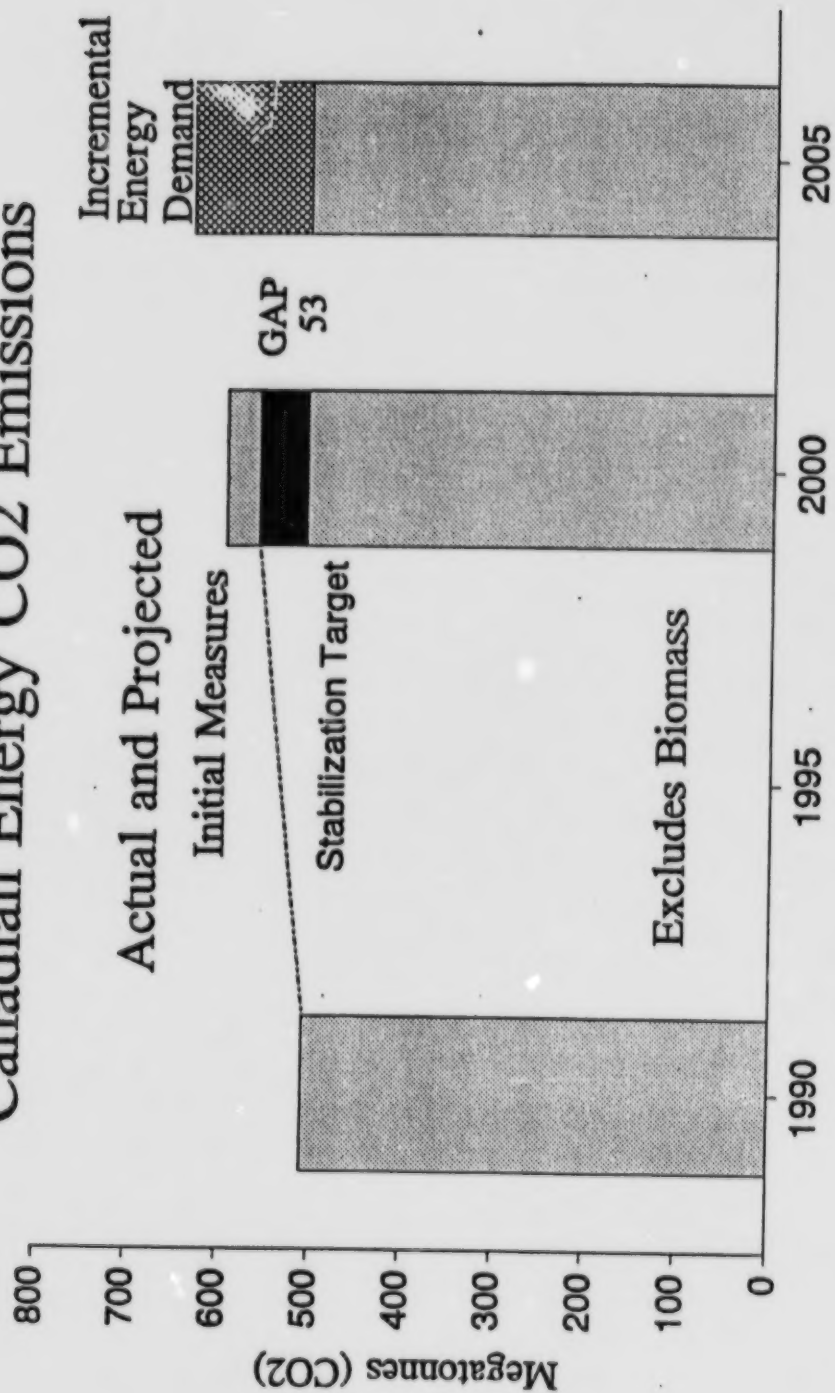
KEY DEVELOPMENT ISSUES:

- Population Growth
- Income Distribution

Carbon Dioxide - Trends

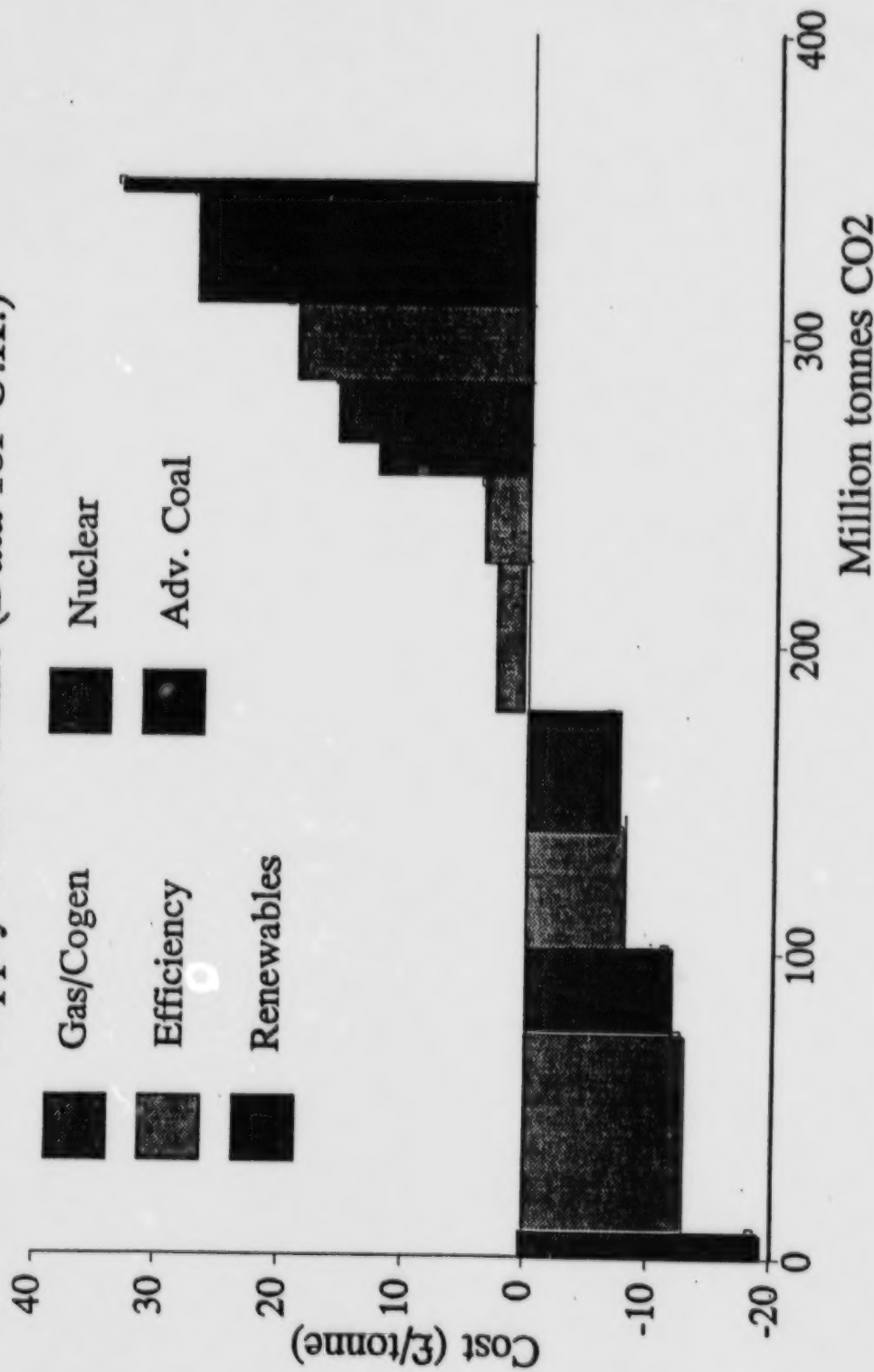


Canadian Energy CO2 Emissions



Greenhouse Gas Abatement Options

Supply Price Chart (Data for U.K.)



The Greenhouse Challenges

- Scientific: Understanding the Earth
- Analytical: Costing Abatement
- Economic: Policy Tools
- Industrial: Timing Transitions
- Political: Managing Trade-offs
- International: Equity & Politics

Sustainable Development

Asking the Right Questions

- What's wrong with present patterns?
- What is our traditional approach?
- What are we trying to achieve?
- What changes are required?

What's Wrong with Present Patterns?

- Reliance on non-renewables from politically unstable regions
-  Waste Emissions
Environmental Quality
- Costs not reflected in prices

The Old Paradigm

What is our traditional approach?

ENVIRONMENTAL PROTECTION

- React and Cure
- Address Symptoms (not causes)
 - Manage the Issue
 - Reduce the Waste
 - Minimize the Impacts

The New Paradigm

What are we trying to achieve?

SUSTAINABLE DEVELOPMENT

- Anticipate and Prevent
- Address Causes (not effects)
- Respect Assimilative Capacity

S.D. Principles - GENERAL

- Stabilize global population
- Maintain internat'l competitiveness
- Improve **quality** of life
- Reduce material expectations
- Strengthen intellectual capacity & technology availability
- Enhance employment opportunities

S.D. Principles - ENERGY

- Improve efficiency of energy use
- Increase energy production
- Reduce environmental emissions
- Enhance energy supply diversity
- Appropriate energy resource pricing

S.D. Principles - RESOURCES

- Respect assimilative capacity
- Improve environmental quality
- Maintain capital stock
(Natural + Man-Made)
- Reduce resource use
- Minimize resource waste

Towards S.D. - ENERGY

What do we need to measure?

- Productivity / Intensity / Efficiency
- Environmental emissions / effects
- Energy supply diversity
- Energy resource pricing

Towards an S.D. Strategy

What changes are required?

- Redefine what is "economic"
- Improve efficiency of energy use
- Reassess RE potential
- Encourage "preferable" sources

Redefine What's "Economic"

- Balance vs. Trade-offs?
- Integration of Env. Effects
- Significance/Magnitude?
- Economic Implications

INTERNALIZE THE EXTERNALITIES!

Improve Energy Efficiency

- Performance standards
- Targetted information
- Institutional changes
- Innovative financing
- Establish "negawatt" market

Tap Renewables Potential

- **Accelerate market entry**
- **Reassess potential/role**
- **Strengthen R,D&D efforts**
- **Address market barriers**

Encourage Preferable Sources

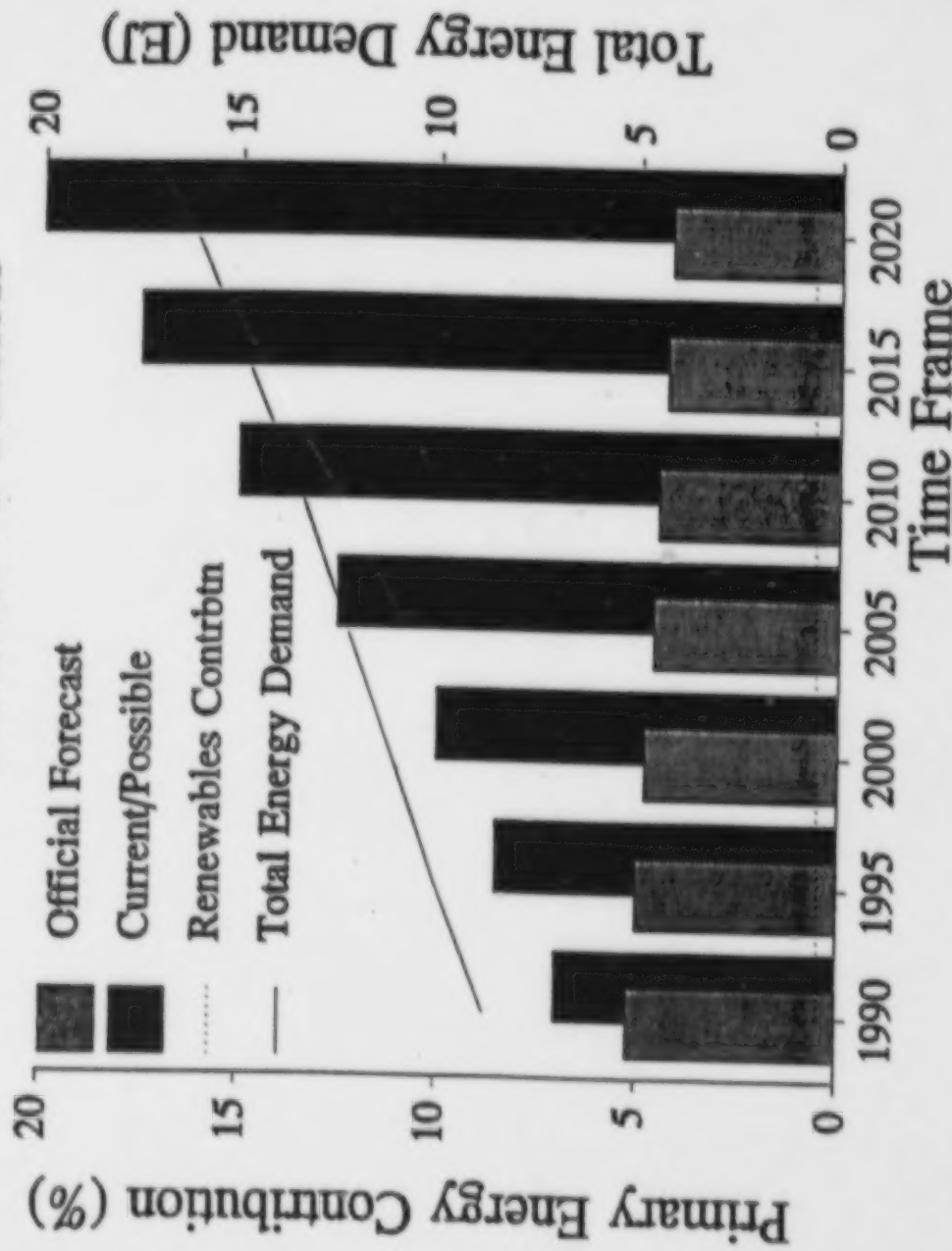
- Life cycle analysis, full cost accounting approach
- Adjust market price signals - innovative economic instruments
- Directly address barriers
- Incentives where necessary

What role for RE Technologies?

- Passive Solar
- Photovoltaics
- Wind Electricity
- Small Scale Hydro
- Biomass Conversion

Renewable Energy Contribution

Forecast vs. Possible



Barriers to Realizing Potential

- Relative Economics
- Technology Readiness
- Access to Capital - Payback Gap
- Institutional Inertia
- Imperfect Information

RENEWABLE ENERGY

Great Hope or False Promise?

- Environmental Benefits ⚙
- Technical Potential ✓
- Industrial/Regional Benefits ✓
- Likely Contribution ?

JEAN-MAURICE CHARRON

BIOGRAPHICAL NOTES

Since 1982, Jean-Maurice Charron has been involved in engineering assessment studies and cost analysis for almost all incineration and energy recovery projects funded by Energy, Mines and Resources Canada.

His previous experience as a plant engineer in the pulp and paper industry and worksite director with General Electric in the field of steam turbines and alternators enabled him to hone his skills in the private sector as well.

Mr Charron is a mechanical engineering graduate of McGill University and holds a diploma in machining from the Hull Technological Institute.

GUY G. RACINE

Notes biographiques

ETUDES

Diplôme en génie chimique de l'école Polytechnique après avoir gradué au Collège Militaire Royal de St-Jean.

CARRIERE

Depuis février 1989, Directeur général de la Régie intermunicipale de gestion des déchets sur l'île de Montréal.

Auparavant, de 1980 à 1989, Directeur gestion des déchets solides pour le groupe SNC.

A ce titre, a dirigé une foule de projets reliés à tous les aspects de la gestion des déchets tant au Canada qu'à l'étranger.

De 1964 à 1980, co-proprétaire de Trecan Limitée, compagnie spécialisée dans l'incinération des déchets solides, liquides et gazeux

Biographical notes

EDUCATION

Degree in chemical engineering from the Ecole Polytechnique, after graduating from the St Jean Royal Military College.

CAREER

Since February 1989, Director General of the Régie intermunicipale de gestion des déchets sur l'île de Montréal (the Island of Montreal Intermunicipal Waste Management Board).

Formerly the Director, Solid Waste Management for the SNC Group, from 1980 to 1989.

In this capacity, headed numerous projects connected with all aspects of waste management both in Canada and abroad.

From 1964 to 1980, co-owner of Trecan Limited, a company specializing in the incineration of solid, liquid and gaseous wastes.

HERBERT CAMPBELL

Notes biographiques

M. H.W. Campbell est présentement directeur de la Division de la gestion des résidus, Centre technologique des eaux usées, d'Environnement Canada à Burlington. Il est titulaire d'un B.A. Sc. en génie civil (1971) et d'un M.A.Sc. en génie sanitaire (1972) de l'Université de Waterloo. Il travaille au Centre depuis 1972. Ses recherches ont porté sur la mise au point et l'évaluation de techniques novatrices de traitement et d'utilisation de boues d'épuration industrielles et municipales.

Biographical notes

Mr. H.W. Campbell is currently the Chief of the Residue Management Division at Environment Canada's Wastewater Technology Centre in Burlington. He received his B.A. Sc. in Civil Engineering (1971) and his M.A. Sc. in Sanitary Engineering (1972) from the University of Waterloo. He has been with the Wastewater Technology Centre since 1972. His research studies have focused on the development and evaluation of innovative technologies from the treatment and utilization of industrial and municipal wastewater sludges.

BACKGROUND

The basic concept of low temperature conversion of sewage sludge to produce fuel products has been known for many years (3). Recently, German researchers have made significant advances in understanding the mechanisms by which sludge is converted to oil (4). They heated dried sludge to 300 - 350°C in an oxygen free environment for about 30 minutes. The researchers postulated that catalyzed vapour phase reactions converted the organics to straight chain hydrocarbons, much like those present in crude oil. Analysis of the product confirmed that aliphatic hydrocarbons are produced, in contrast to all other pyrolysis processes, which produce aromatic and cyclic compounds, regardless of the substrate (e.g., sludge, cellulose or refuse). The German researchers demonstrated oil yields ranging from 18-27% and char yields from 50-60%. The oil had a heating value of approximately 39 MJ/kg and the char about 15 MJ/kg.

Based on the potential of this process, Environment Canada conducted preliminary batch, bench-scale experiments in 1982 to confirm the results. After confirmation, Environment Canada designed, fabricated and patented a continuous-flow bench-scale reactor and embarked on a major technology development and demonstration program.

BENCH-SCALE STUDIES

The bench-scale reactor system is shown schematically in Figure 1. The system has a capacity of 1 kg of dried sludge per hour and has been used to evaluate process performance and to generate design information.

The reactor is subdivided by a helical gas seal into a volatilization zone and a char/gas contact zone. Solids retention time (SRT) in the reactor is controlled by varying both the sludge feed rate and the reactor inventory. Sludge is fed to the reactor by a calibrated screw conveyor and travels through the reactor by means of the reactor conveyor. Volatilized material is withdrawn in the first zone and is contacted with the char in either a co-current or a counter-current mode in the second stage. Product vapours are condensed externally in a water cooled condenser and separated into oil and reaction water. The non-condensable gas (NCG) is vented to a stack. Inert gas is used to purge the system of oxygen and the operating pressure is generally less than 2 000 pascals. The system has been operated using twenty-two different sludges from Canada, USA and the United Kingdom. A summary of representative process performance data is shown in Table 1. Additional details on the results achieved during this phase of the development are available in the literature (5,6,7).

The information in Table 1 has been separated into mixed raw and anaerobically digested wastewater sludges. The results show that the oil yield from raw sludge is generally greater than that from digested sludge. This is as expected because the volatile material which is destroyed through the digestion process represents precursors for the oil which would have been generated in the conversion process. Oil yields range from a low of 13% for an anaerobically digested sludge to a high of 46% for a mixed raw sludge, and are primarily a function of the operating temperature and the sludge source. Char yields vary from 40% to 73% at the optimum operating temperature. NCG yields vary from 3% to 12% and are primarily a function of operating temperature. Production of reaction water varies from 3 to 16% and does not appear to be directly related to any of the operating variables. Thermal efficiencies of greater than 95% are routinely obtained with the bench-scale reactor.

From an operational point of view, the reactor has proven to operate equally well with either raw or digested sludge. The main exceptions are the amount of oil produced, (higher quantities from raw sludge) and the oil from a digested sludge has a lower viscosity than the oil from raw sludge from the same source. In general, oils from digested sludges tend to exhibit lower viscosities than those from raw sludges.

The elemental characteristics of the oil are quite stable over a wide range of operating conditions. Typical values for C, H, O, N and S are 76%, 11%, 6.5%, 4% and 0.5% respectively. Generally the oil contains less than 7% oxygen, but levels as low as 2% have been achieved.

The relationship between temperature and oil yield, is illustrated for a number of sludges in Figure 2. Oil yield is calculated based on volatile solids rather than total solids which normalizes the results to account for the fact that raw sludge generally has higher volatile solids than digested sludge. Even with this normalization, the yield from raw sludge is still generally higher than that from digested sludge. This indicates that the volatile solids in the raw sludge contain more of the components which are ultimately converted to oil than do those in digested sludge. The volatile solids which are destroyed during digestion constitute a very high percentage of the oil precursors.

Figure 2 shows that although the oil yield varies significantly from sludge to sludge, the effect of temperature is identical for all sludges. The oil yield increases with increasing temperature until it reaches a maximum in the 400 to 450°C range. Above the optimum temperature the yield begins to decrease as conditions favour the formation of increasing quantities of non-condensable gas. Sufficient data is not available to pinpoint the exact shape of the temperature/yield curve, but it is obvious that the optimum, for all practical purposes, is a range as opposed to one specific point. In engineering terms, this is extremely

important because it indicates a very stable operating system (i.e., if the temperature fluctuates to some degree due to other perturbations within the system, the process will not fail). No clear relationship between temperature and oil calorific value has yet been identified but the viscosity of the oil has been found to decrease with increasing temperature, indicating that some thermal cracking of the oil is occurring.

PILOT-SCALE STUDIES: CANADA

In 1985 Environment Canada contracted with Petro Sun International Incorporated (PSI) to design, construct and operate a 1 t/d (40 kg/h) pilot-scale conversion reactor system to confirm the laboratory-scale results and the projected energy savings from the oil from sludge technology. A schematic of the pilot plant system is shown in Figure 3. It consists of a 1 m³ storage bin, a sludge feed system, a 25 cm diameter x 3.2 m long reactor, a char discharge system, a packed-tower direct-contact condenser, an oil-water separator and a self-contained propane/NCG fired boiler to provide hot flue gas for reactor heating. The configuration and operation of the reactor are exactly the same as described for the bench-scale reactor with the exception of the method of heating. The entire pilot plant is mounted on a 1.7 m x 7.4 m skid and is readily transportable.

The system was delivered to the Regional Municipality of Hamilton-Wentworth, Woodward Avenue Sewage Treatment Plant in September 1986. Since that time, a number of modifications have been made to improve both performance and ease of operation. Although fine tuning of the system continues, the current configuration has proven to satisfy the original design criteria. The pilot plant has been operated on three different sludges. The results have generally confirmed that the system is capable of transporting both the sludge and the char, sufficient heat capacity is available to reach conversion temperatures at relatively low solids retention times, the throughput capacity of 40 kg/h can be reached, the products can be separated and performance is similar to that achieved with the bench-scale system. The only aspect of the pilot plant which was not satisfactory was the separation of the oil and reaction water. When the density of the oil was very close to that of water, problems were encountered trying to discharge the oil and water separately. As a result, the gravity decanter was replaced by a disc centrifuge and the problem was alleviated.

Table 2 shows results from the pilot plant for one raw and two digested sludges. For a specific sludge, the data from the bench-scale and the pilot-scale systems compare well in terms of product yield and quality. As predicted by the bench tests, the oil yield from the raw sludge is higher than from the digested sludge while the char yield is lower. The oil from digested sludge also has a significantly lower viscosity. Elemental analysis shows that oils from the same sludge but generated on different systems (i.e., bench and pilot-scale), are very similar.

Following the completion of the program determining the effect of operating parameters on the performance of the pilot plant, the pilot plant was operated in a production mode to generate a large quantity of oil for future work. The pilot plant was operated at 450°C and a 25 minute solids retention time for 10 to 12 hours per day for several days using the sludge from Atlanta. The total volume of oil generated during this period was approximately 2000 L. The oil was used to carry out extensive characterization studies and to evaluate alternative end-uses for the product. These studies will be discussed later in the paper.

PILOT-SCALE STUDIES: AUSTRALIA

As part of the overall commercialization process, Environment Canada licensed the OFS technology to a Canadian company, Enersludge Inc, a joint venture of SNC (Canada) and Campbell Group (Australia). In order to be able to generate data on local sludges, Enersludge (Australasia) Pty Ltd constructed a second generation 1 t/d pilot plant in Perth, Australia. The pilot plant is essentially the same as the one in Canada with one major exception. The reaction is heated by burners mounted directly on the reactor shell rather than by hot flue gas from a propane fired boiler. There are also some improvements in the sealing of the feed and discharge zones which allow operation at pressures up to 25 kPa. The pilot plant has been used to develop a database on Australia sludges and in general, the results are similar to those obtained in Canada.

In 1989 a demonstration program, involving pilot testing of all unit operations in an integrated OFS plant was conducted for the Sydney Water Board at their Malabar Sewage Treatment Plant (8). The objectives of the program included the development of detailed design data, the generation of environmental data, the assessment of end-uses for the oil and the refinement of cost estimates for a 60 t/d facility. The process train which was evaluated consisted of a belt filter, a direct flue gas dryer, the OFS reactor system and a fluid bed combustor. Only the environmental data will be discussed in this paper.

The study was conducted on anaerobically digested primary sludge from the Malabar plant. Table 3 lists the average concentrations for the heavy metal and organic contaminants identified in the sludge. The heavy metal concentrations are indicative of a significant industrial contribution to the sludge. The copper concentrations are high by North American standards but are representative of Australian sludges.

Numerous organochlorine contaminants were identified in the sludge but hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB) were the only ones consistently detected at measurable concentrations.

The sludge was first dewatered on a belt press to between 30 and 35% solids and then dried to 95% solids by a direct flue gas dryer. Analyses indicated no detectable loss of either heavy metals or organochlorines (OC) through the dewatering or drying stages.

The dried sludge was processed through the OFS reactor system and the contaminants measured in the oil, char and reaction water. Mass balances conducted around the reaction products showed that with the exception of arsenic (47%) and mercury (10%), the heavy metals were essentially retained in the char (98-106%). The balance of the arsenic was accounted for in the other reaction products but with mercury, the mass balance accounted for only 25%. This is consistent with earlier results from the program in Canada. Small concentrations of HCB (1.0 mg/kg) and PCB (0.48mg/kg) were found in the oil but levels of both contaminants were non detectable in the char and reaction water. It was not expected that HCB or PCB would be present in the non condensable gas, since at 35° C both compounds have minimal vapour pressure. Based on the concentration of the compounds in the oil, the destruction efficiencies through the OFS reactor were calculated to be greater than 85% for HCB and greater than 75% for PCB.

The char was combusted in a 150 mm pilot fluid bed combustor (FBC) at a feed rate of approximately 1 kg/h and bed temperatures ranging from 789° C to 876° C. Excellent organic carbon combustion efficiency was achieved ranging from 99.992 to 99.996%. Nitrogen oxides were relatively stable at 300 to 400 ppm. At 786° C in excess of 99.7% of the heavy metals, with the exception of mercury, were retained in the ash. Approximately 8% of the mercury in the char was accounted for in the FBC products, 5.4% in the ash and 2.6% in the flue gas. Organochlorine compounds were not detected in either the char or the FBC off-gas. A maximum of 24 mg/kg of polycyclic aromatic hydrocarbons (PAH) were detected in the char and off-gas analysis indicated a PAH destruction efficiency of greater than 96%.

The bed ash from the FBC run at 786° C was leached using the USEPA Toxic Characteristic Leaching Procedure (TCLP) which New South Wales has accepted as a definition of whether a solid waste would be classified as hazardous or non-hazardous. All parameters were well within the limits set by New South Wales and the ash would be classified as non-hazardous.

Off-gas analysis from both the dryer and the OFS reactor also showed that air emissions would easily meet state requirements for heavy metals and organochlorines.

PRODUCT CHARACTERIZATION STUDIES

In conjunction with the pilot plant program, there has also been activity relating to the characterization of the end products, primarily the oil fraction. The studies have been aimed at either gaining a better understanding of the fundamental mechanisms of oil formation or identifying alternative end-uses based on specific characteristics of the oil.

In 1984 a contract was awarded to Chemical Engineering Research Consultants Ltd. (CERCL) to evaluate the fundamental mechanisms involved in the thermal liquefaction of sewage sludge. The study concluded that thermally produced sewage sludge oils are mainly lipid in origin, although chemical reactions do lead to incorporation of nitrogen from protein and nitrogenous material (9). Raw sludges produce higher yields of oil, but these usually have a higher viscosity than oils from digested sludges. The raw sludge oils, unlike the oils from digested sludges, contain considerable carboxylic acids. Surfactant type molecules complicate the removal of water from the oil. A simple thermal process operating at reactor temperature was developed which enhances the oil water separation. The process results in a low viscosity, homogeneous oil which contains less than 1% water. The nitrogen content can be reduced to 2% or less, whereas the sulphur content remains at 0.5%. Approximately 10% of the oil may be lost in this process. The product is miscible with diesel fuel in all proportions. A very slight precipitate, which results on blending the oil and diesel fuel, can easily be removed by filtration.

In 1989, the Wastewater Technology Centre, the Canada Centre for Mineral and Energy Technology (CANMET) and Enersludge entered into a joint program to carry out research on the sludge derived oil (SDO). The SDO was first characterized in terms of basic fuel properties. The oil was then fractionated into various fractions and each fraction characterized in terms of both fuel properties and quantities of hydrocarbons, and polar and aromatic compounds present. Methods to remove polar compounds and thus enhance the compatibility of SDO and conventional diesel fuel were investigated. The technical feasibility of upgrading the SDO by catalytic hydroprocessing was also evaluated.

When this program was initiated, the work was very much oriented to improving the quality of the SDO as a transportation fuel. It was generally assumed that the most valuable end-use would be either as a "neat" diesel fuel or blended in some ratio as a diesel fuel extender. Although some success in this area was achieved, it soon became evident during the characterization phase that the SDO was much more valuable as a source of specialty chemical products than as a fuel. Subsequent work was therefore refocused towards the development of such products. The results of these studies have been extremely encouraging and have led to the initiation of a number of patent applications. These products have been identified to have a high market value, significant commercial demand and a high level of SDO utilization.

ENGINEERING AND COST STUDIES

Based on the positive results achieved with the 1 kg/h bench-scale reactor system, Environment Canada contracted with Zenon Environmental Inc. in 1984 to assess the commercial viability of the technology. This study generated a detailed process design for a 25 t/d conversion plant and assessed the economics in comparison to existing sludge management options. A detailed discussion of the alternative sludge disposal options is available in the literature (7). The study found that the technology based on the lab results appeared to be economically viable and warranted further development.

One of the concerns identified in the Zenon study, was the degree of accuracy related to existing sludge incineration costs. In many cases sludge facilities have been constructed in a number of phases over several years and plant personnel do not have a good estimate of the overall costs. In order to address this problem, Environment Canada contracted with Proctor and Redfern Ltd. to develop total sludge treatment costs at four integrated sludge management plants in Ontario (10). The sludge treatment train was considered to include digestion, thickening, dewatering, conditioning, incineration and ash disposal, although not all unit processes were present in each plant. Capital costs were taken from actual construction contracts and updated to July 1986 by applying the Engineering News Record Construction Cost Index, Toronto. Operating and maintenance costs were determined from plant records and discussions with plant personnel. The costs were presented in a variety of ways but the most useful method was determined to be total cost (O&M plus amortized capital) per unit tonne of raw sludge generated. The capital component was calculated by amortizing the total capital cost over 20 years at 10% interest. At existing flows, which range from 36 to 67 t/d (on a dry solids basis), the total sludge costs range from \$350 to \$1042/t (1986 Cdn\$). This represents 35%, 50%, 51% and 52% of the total wastewater treatment costs, for the four plants surveyed. The sludge operating costs represent 48 to 60% of the total plant operating costs while the capital costs related to sludge, account for 32 to 51% of the total plant capital costs.

Projected costs for the oil from sludge technology have been developed in a variety of ways. Preliminary costs, based on data from the lab-scale unit, were prepared for a 25 t/d plant in 1985 as part of the Zenon study. These costs were updated by Petro Sun in 1986 based on additional data and scaled up to 65 t/d. The most accurate costs currently available are from a proposal by Enersludge for a 45 t/d, oil from sludge facility for Metro Toronto. The capital cost, which includes dewatering, conditioning, drying, conversion, condensing, oil/water separation, char combustion and ash disposal was estimated at \$17.5 M plus \$0.5M for performance evaluation and environmental assessment. Based on an amortization rate of 11% per year (over 20 years) and an annual operating cost of \$2.2 million per year, this results in a total unit cost of \$295/t of dry solids. This cost, which does

not include any value for the oil, compares favourably with the minimum cost of \$350/t reported by Proctor and Redfern for incineration.

It should be noted that the costs generated by Proctor and Redfern represent the costs required to build the plant as it existed in 1986. It does not account for the fact that if that plant were being designed today, many improvements and operating strategies, which represent current state-of-the-art, would be incorporated into the design and result in a significantly lower cost. However, the projected cost savings with conversion are of a sufficient magnitude to warrant demonstrating the technology at full-scale and confirming whether these estimates can be achieved in actual practice.

FULL-SCALE DEMONSTRATION PLANS

It is recognized that in order for the OFS technology to be accepted by wastewater treatment authorities as proven technology, it will be necessary to demonstrate it at full-scale. Therefore, considerable effort has been expended over the last year to identify a suitable candidate site and to assemble the required funding package. In July 1990, the Municipality of Metropolitan Toronto agreed to construct a 45 t/d OFS facility at their Highland Creek sewage treatment plant. The demonstration plant will consist of centrifugal dewatering, direct flue gas drying, OFS and fluidized bed char combustion and will replace a Porteus heat treatment system coupled with multiple hearth incineration. The plant is currently in the design stage and it is expected that it will be operational by early 1992. Since there is always an element of risk associated with the construction and operation of the first prototype of any process, a financial package has been developed which includes contributions from the Federal Government (Environmental Canada; Industry, Science and Technology Canada), the Provincial Government (Ministry of the Environment), the Municipal Government (Metropolitan Toronto) and the licensee (Enersludge Inc.). Assessment of the full-scale facility will include an evaluation of economics, process performance and environmental acceptability. At the time of writing, a proposal for a 180 t/d OFS facility was being considered, along with a number of other sludge management alternatives, for the city of Sydney, Australia. It was expected that a decision on the successful technology would be announced by mid-autumn. Other cities throughout the world have expressed significant interest in the technology but no other definite commitments have been made.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the technical support on the contractors on various components of the program and the financial support provided by the Department of Supply and Services and the Federal Panel on Energy Research and Development.

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TABLE 1. BENCH-SCALE OPERATING CONDITIONS AND RESULTS

	Raw	Digested
Feedrate (g/h)	750	750
Temperature (°C)	450	450
Solids Retention Time (min)	20	20
OIL		
Yield (%)	22-46	13-29
Viscosity (cstks)	23-168	9-87
Calorific Value (MJ/kg)	33-38	32-42
CHAR		
Yield (%)	40-66	41-73
Calorific Value (MJ/kg)	7-23	6-17
NCG		
Yield (%)	3-12	4-12
Calorific Value (MJ/kg)	2-19	4-18
REACTION WATER		
Yield (%)	3-15	7-16

TABLE 2. PILOT-SCALE OPERATING CONDITIONS AND RESULTS

	ATLANTA (Raw)	ROCKFORD (Dig)	HAMILTON (Dig)
Feedrate (kg/h)	24	24	24
Temperature (°C)	450	450	450
Solids Retention Time (min)	25	25	25
OIL			
Yield (%)	27	11	12
Viscosity (cstks)	62	20	24
Calorific Value (MJ/kg)	31	34	40
CHAR			
Yield (%)	43	71	69
Calorific Value (MJ/kg)	16	8	6
NCG			
Yield (%)	9	6	7
Calorific Value (MJ/kg)	5	7	7
REACTION WATER			
Yield (%)	15	12	12

TABLE 3. DIGESTED SLUDGE CHARACTERISTICS

Parameter	mg/kg
Arsenic	3.1
Cadmium	44
Chromium	615
Copper	1187
Lead	267
Mercury	7
Nickel	198
Zinc	1999
Hexachlorobenzene	1.3
Polychlorinated Biphenyls	0.32

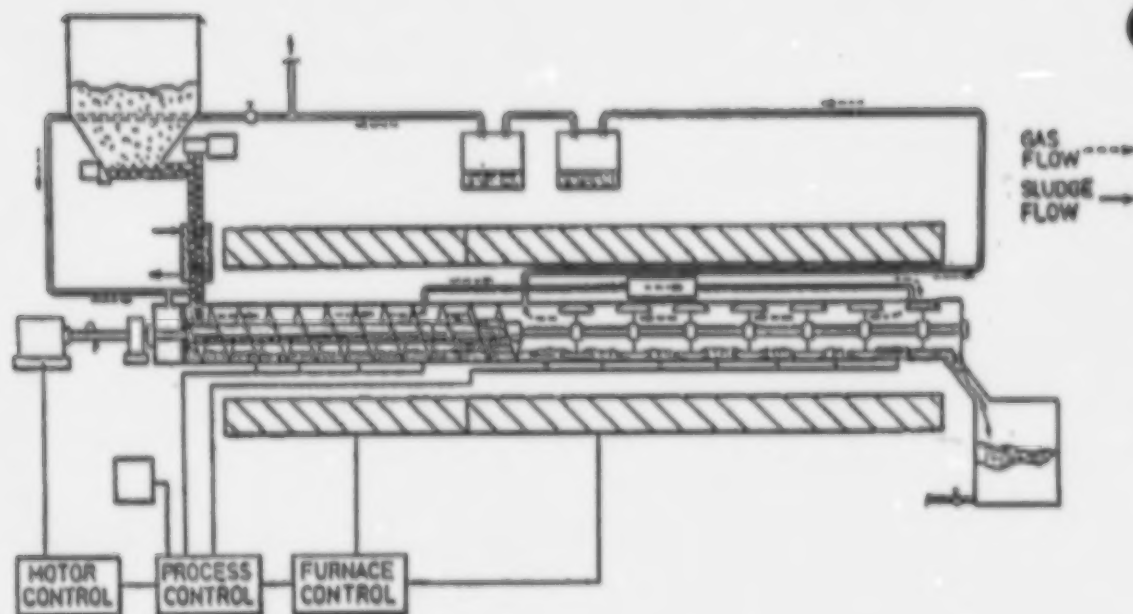


Figure 1. Schematic of bench-scale reactor

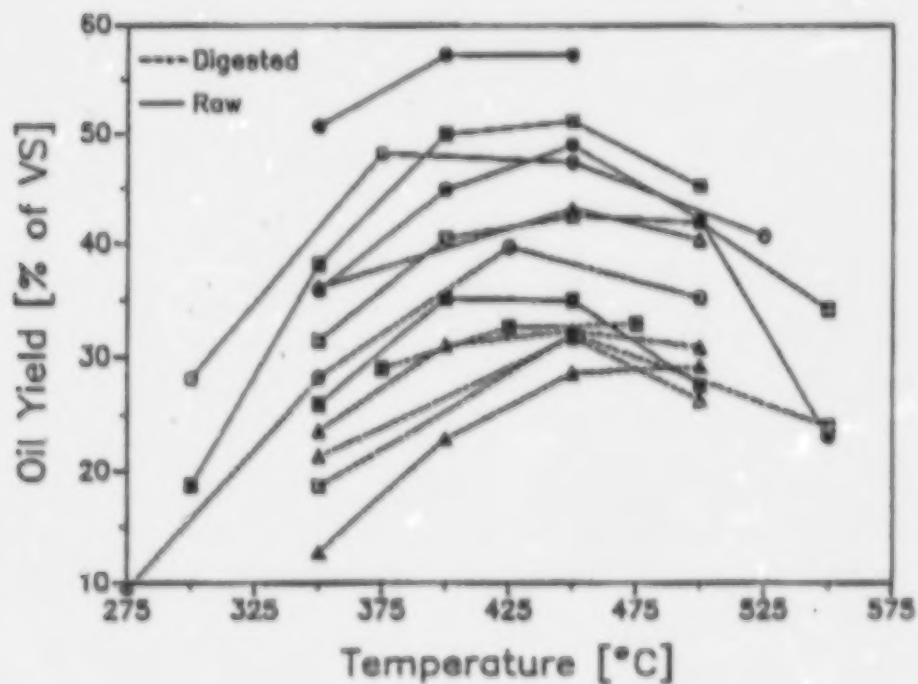


Figure 2. Effect of temperature on oil yield (bench-scale)

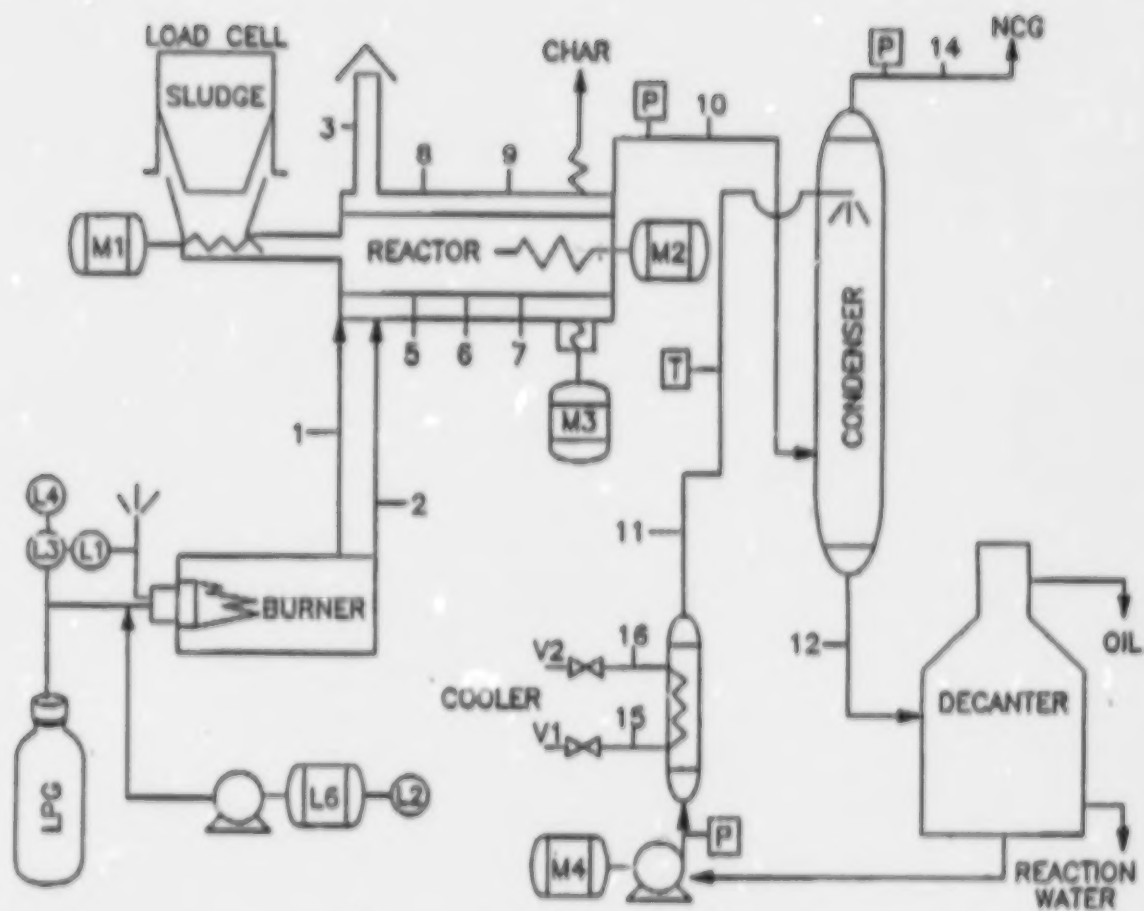


Figure 3. Schematic of pilot-scale conversion system

PRESENTATION BY : MARCEL RISI
CQVB

Forest Biomass Research
in Quebec

"SUMMARY"

20-21/03/91

RESUME OUTLINE

MARCEL RISI

Education

Collège des Jésuites, Classics, 1951

Collège université Laval, Philosophy of Science, 1953

Université Laval, Physics, 1957

Ecole Polytechnique Fédérale Zurich, Switzerland, Physics, 1962

Experience

1962-1967

Professor, Université de Sherbrooke

1967-1970

Director General, Transcripta Inc, a scientific publishing and audio-visual services firm

1971-1980

Director of Technological Data, Centre de recherche industrielle du Québec

1980-1983

Marketing Director, Centre de recherche industrielle du Québec

1982-1983

Scientific consultant, Science and Technology Secretariat

1983-1985

Assistant Deputy Minister, Department of Science and Technology and Department of Higher Education, Science and Technology

1985 -

Chairman and Director General, Centre québécois de valorisation de la biomasse



Background

Owing to both its energy potential and the environmental problems it poses, forest residue in Quebec is, like urban waste, a resource which cannot be overlooked when it comes to energy management.

Size of the forest biomass

The increasingly stringent standards of the Quebec Department of the Environment and the implementation of Bill 150, the new act regulating public forest activities, make wood residue, from the forest to the plant, a matter of ever more pressing concern. According to Quebec Department of Energy and Resources statistics, forests are being harvested at an annual rate of 32 million cubic metres. The pulp and paper and lumber industries generate a yearly average of 4.15 million TMA of logging residue in cutting and silviculture treatment areas, and 3.3 million TMA of barking residue and sawdust in the timber yards of sawmills and pulp and paper plants. To this may be added the 170,000 tonnes of sludge produced by pulping units.

Problem

These figures illustrate both the environmental and economic problems of the disposal and exploitation of residual wood fibre. These two problems in turn rest upon a more fundamental and equally pressing issue, that of the availability of **persons with innovative research and development ideas** to solve them.

In broad terms, solutions to the problem of forest residue are closely linked to the value which can be added to this waste and which, in the current energy context, must go beyond energy alone. The biomass must be seen as a resource for the replacement of hydrocarbons in the petro-chemical, as well as the energy, field.

This means that forest biomass research is aimed at developing new procedures for processing and exploiting forest residue, with emphasis on technologies for fractionation of the biomass. Planned products include: low yield papermaking pulp, fine chemical products derived from lignin extracts, adhesives made from lignin, special fibreboard and cogenerated electrical and thermal energy.

The role of CQVB

A transfer and community leadership organization, CQVB disseminates information by making it part of the transfer process, and through its role in co-ordinating research consortia.

During its first mandate (1985-1991), CQVB invested \$2.3 million in the field of forest biomass research, or 30% of its R&D budget. This investment generated \$4.2 million in outside contributions, or 24% of total outside R&D contributions, and in January 1991, 21 forest sector projects had been completed or were underway.

Subject: Utilizing By-product Waste as Electric Furnace Feedstock

Sponsor: Albright & Wilson Americas

Presenter: Jacques C. Bureau

Jacques C. Bureau is a Senior Advisor to Albright & Wilson Amérique and a former Site Manager of the Varennes Quebec Plant. Jacques first joined Albright & Wilson Americas in 1962 as a Project Engineer at Varennes and later worked for their Buckingham Quebec Plant. Following a sojourn of nine years in which he was employed by others, Jacques returned to Albright & Wilson Americas in 1980 and was reappointed Plant Manager, Varennes with the additional specific mandate to tackle plant environmental problems one of which was the management of current and accumulated solid rejects. In mid 1989, he moved from Plant Management into the newly created role of Manager, Quebec Public Affairs where his efforts have been directed to improving relations between the complex chemical industry and the community. He also has the important task of assisting in the implementation of the various steps of the Responsible Care initiative in Quebec for the chemical community.

Albright & Wilson Americas, a Tenneco Inc. Company with plants in the United States, Canada and South America, is a major producer of inorganic and organic chemicals, chemical systems and engineering services.

"Utilizing By-Product Waste As Electric Furnace Feedstock"

JACQUES C. BUREAU

Abstract

This phosphorous producer has to discard an important portion of its raw materials because they are physically incompatible as feedstock for its arc furnaces. Paradoxically, while exploring potential uses for a new reject, the solution was found.

The new reject (phosphoric acid) is used as an agglomerating agent for the rejected raw material portion (rock & coke) and both materials are formed into briquettes which are a compatible feedstock for the arc furnaces process.

This project resulted in increased efficiency, energy savings and environment improvement.

Biographical Notes

DR. HASSAN A. HAMZA

Graduated with a B.Sc. degree in Mining and Petroleum Engineering from the University of Cairo, Egypt and obtained a Ph.D. degree from the University of Newcastle-Upon-Tyne, England in solid-liquid separation in 1967.

He has worked as a professor in various universities in Egypt and also worked in the National Coal Board of England and for the Black Sands Company of Alexandria.

He is presently the Manager of the Fuel Processing Laboratory of CANMET in Devon, Alberta where work is carried out mainly based on Fine Particle technologies.

"Oil Sands Sludge"

DR. HASSAN HAMZA

Abstract

World Tar Sands reserves are estimated to be in excess of 500 billion cubic metres of bitumen in place of which 270 billion cubic metres approximately exist in Alberta. Suncor and Syncrude, the two Alberta operating companies, process about 150 million tonnes of oil sands per year using surface mining and the Clark Hot Water process for bitumen extraction. This process produces tailings at a rate of approximately 30 million tonnes of sludge per year.

Tar sands sludge is a mixture of fine mineral particles and residual bitumen that have a very high water holding capacity. The sludges contain 70 % water after 20 years of settling in the pond.

Many studies have been conducted over the years, particularly directed towards engineering solutions. Recently, more emphasis has been placed on studying the fundamentals of the sludge stability to serve as a basis for the formulation of a solution for disposal of accumulated sludges as well as for treatment of sludges produced in the future.

Several aspects of the expertise developed in studying tar sands sludge lend themselves readily to characterization and treatment of other sludges such as the mineral industry and municipal sludges.

1

OIL SANDS SLUDGE

BY

H.A. HAMZA

2

WORLD'S OIL SANDS RESOURCES

(Billion m³)

World	630
Canada	400
USSR	192
USA	7
Nigeria	7

3

EXTRACTION

◆ This slide shows the different processes involved in the synthetic crude production. This includes:.

- ◆ a) Open-pit mining (dragline, stakker, reclaimer)
- ◆ b) Extraction
- ◆ c) Upgrading
- ◆ d) Pipelining

4

- ◆ This slide shows the drag line.
- ◆ The bucket of the drag line is approximately 10 m³.

Synchrude, for example, mines 100,000 tonnes per day using their drag line.

5

- ◆ The tar sands is feed to the extracting plant where it is mixed in a slow rotating drum to break down the aggregates and loosen the bitumen.

6

- ◆ The dispersed slurry is fed to a conical vessel and time is allowed for the bitumen to float to the surface.
- ◆ Sands settle to the bottom.
- ◆ A "soupy" mixture of clays, minerals, and bitumen and water stays in the middle.

7

- ◆ The bitumen from the extraction plant is fed to the upgrading plant. The upgrading process includes hydrotreating and fluid or static cokers.
- ◆ The products are:
 - ◆ Synthetic crude
 - ◆ Sulphur
 - ◆ Coke
 - ◆ Gases
 - ◆ Light products

8

WATER BALANCE (Million tonne/year = mt/y)

- ◆ The water system is almost a closed circuit with only relatively small quantities of water entering or leaving.
- ◆ Water for steam generation (25-30 mt/y) and make up water is drawn from the Athabasca River.
- ◆ Approximately 5 mt/y and approximately 10 mt/y are also externally added to the system as a constituent of the tar sands feed and as precipitation and drainage.
- ◆ Approximately 6 mt/y goes out of the system in evaporation losses and 35 mt/y are locked in the pond sand and sludge.
- ◆ Out of the 135 mt/y of water associated with the tailing which discharges into the pond 100-110 mt/y are recovered and recycled to the extraction plant.

9

COMPONENTS OF TAILINGS

- ◆ One cubic metre of tailings slurry contains approximately 0.03 m³ of bitumen, 0.2 m³ of sandy deposit and the balance in fine tails suspension.

As one can see from this slide, most of the water ~.4 m³ is recycled while .15 m³ is locked with the sand deposit and the balance remains associated with the fine tails or sludge.

10

SLUDGE VOLUME

- ◆ This slide shows the actual and projected sludge volumes.
- ◆ It shows that the sludge volume will reach 300 million m³ of sludge.

#11 FINE TAILS VOLUME

- ◆ This shows that the growth of sludge is predicted to continue in a straight line to the year 2018.

#12 SYNCRUDE SITE PLAN

- ◆ This slide shows the size of the tailings pond compared to the rest of the site. The pond is as big as the mine itself.
- ◆ Keeping in mind that it covers valuable tar sands deposits.
- ◆ Looking at the scale one can see that the pond is approximately 7 km in length and 3 km (on average) in width. The total areas of the pond is estimated at 23 km².

#13 AERIAL PHOTOGRAPH OF SITE

- ◆ This slide shows an aerial shot of the Syncrude and Suncor sites.

#14 TAILINGS DISCHARGE

- ◆ This slide shows the tailings discharge into the pond.

#15 TAILINGS POND SCHEMATIC

- ◆ This slide shows a vertical cross section schematic of the pond to scale.
- ◆ The depth is magnified (in the insert) to show the different zones.

#16

CROSS SECTION OF TAILING POND

- ◆ This slide shows an exaggerated vertical cross section of the water areas of the pond.
- ◆ It shows that the structure sludge in the pond is a function of depth.
- ◆ The % solids increases with depth.

#17

RECOVERY OF FREE FLOATING BITUMEN

- ◆ This slide shows a Barg for recovery of free floating bitumen.

Despite this procedure,

#18

GENERAL VIEW

- ◆ This slide shows a general overview of the pond.
- ◆ Scarecrows had to be installed to scare birds away from landing on the pond.

#19

SLUDGE STRUCTURE

- ◆ What is sludge?

A "soupy" mixture of mineral fines, water and bitumen.

- ◆ This slide shows the structure under the scanning electron microscope (SEM)
- ◆ It also shows that coarser sand is entrapped in the structure.

2 0

This slide shows a close-up of sludge structure.

2 1

RECLAMATION OPTIONS

Dry Landscape Options

- ◆ Capture with coarse sand fraction
- ◆ Dewatering by mixing with undersaturated clay overburden
- ◆ Freeze/thaw or Evapotranspiration

Wet Landscape Options

- ◆ Cap contained material with a water layer

2 2

WET LAND RECLAMATION OPTION

- ◆ Analogous to land reclamation
- ◆ Mixing potential of layers is low
- ◆ Impact of sludge release water minor
- ◆ No acute or chronic toxic effects observed

2 3

- ◆ This slide shows an overview of wet lands option.

24

EFFECT OF STORAGE ON TOXICITY OF POND WATER

Bioassay	Start	1 year	2 years
<u>Fish</u>			
96 hr LC50	< 10%	> 100%	>100%
21-day survival	0%	80%	100%
<u>Daphnia</u>			
96-hr LC50	<10%	>100%	>100%
21-day survival	0%	60%	35%
<u>Microtox</u>			
15-min EC50	<30%	>199%	>100%
15-min EC20	<10%	25%	35%

25

DRY LAND OPTION

- ◆ This slide shows the Spreader method mixing of overburden mixing with sludge.

26

DRY LAND OPTION

- ◆ This slide shows the Truck/Dozer method of mixing overburden with sludge.

27

SLUDGE DISCHARGE

- ◆ This slide shows an example of sludge discharge during Dry Land options.

28

2018 MINE STATUS

- ◆ This slide shows the ultimate plan contemplated by Syncrude, for example:
 - ◆ It shows both wet land option and dry land option
 - ◆ Notice that it assumes that the tailings pond volume will stay constant
 - ◆ This may only be achieved if other options are introduced such as enhancing the consolidation of sludge in the pond

29

As you would conclude from the presentation so far:

"Sludge ponds impair the environment, cause mine planning problems, and take up too much space".

30

- ◆ 20 years of research by industry, universities, government and "backyard" inventors has made no significant fundamental difference on how sludge is managed.
- ◆ As you have noticed most of the considered solutions are engineering in nature.

31

WHAT IS THE PROBLEM?

- ◆ It is clearly a solids-liquid separation problem.

32

WHAT IS THE PROBLEM?

- ◆ "Fine particles difficult to separate"

3 3

WHAT IS THE PROBLEM?

Difficulty in scale-up from laboratory research to field due to:

- ◆ Irreproductibility due to heterogeneity
- ◆ Fundamental work largely on ideal system (e.g. latex)
- ◆ Necessary expertise unavailable in Canada. (Holland, Potsdam, Bristol)
- ◆ Multidisciplinary approach essential but difficult.

3 4

WHAT IS REQUIRED?

- ◆ The geotechnical properties of sludge is based on its physiochemical structure and properties.
- ◆ An improved understanding of these properties is required for any significant advances to control the sludge system.

3 5

SLUDGE FUNDAMENTALS CONSORTIUM

- ◆ A consortium is formed between different organizations who have interest and expertise in this area:

Members

CANMET
SYNCRUDE
SUNCOR
AOSTRA
NRC
ARC
ENVIRONMENT CANADA

Budget: approximately \$3M/yr for 3 years.

#36

THE GOAL OF THE CONSORTIUM

The goal of the consortium is to determine the physical and chemical properties of the sludge system in order to learn how to manipulate the system to release bitumen and hasten sludge consolidation in an environmentally acceptable manner and within a reasonable time frame.

#37

BENEFIT FOR GOVERNMENTS

- ◆ A firm basis for regulatory decisions
- ◆ Enhanced attractiveness of oil sand developments.

#38

BENEFIT FOR THE COMPANIES

- ◆ It will provide the companies with a firm basis for making sludge management decisions.
- ◆ Future volume predictions
- ◆ Sludge minimization schemes
- ◆ Environmental impact

#39

The experience gained in this program have allowed CANMET to extend its expertise to other sludges such as:

- a) Mineral
- b) Oil refineries
- c) Coal fines
- d) Industrial
- e) Municipal

#40

- ◆ This slide shows a very fine mineral acid leach product going through small cyclone before treatment.
- ◆ Notice that both products of the cyclone are the same i.e. no separation.

#41

- ◆ This slide shows the same after treatment
- ◆ The overflow shows clear Leach solution.

#42

- ◆ This slide shows another example of minimal applications.
- ◆ In this case, it was an alkaline leach.

Again, no separation for the untreated pulp.

#43

- ◆ Shows the same after treatment
- ◆ Clear leach solutions in the product of the cyclone overflow.

Notes biographiques

CLAUDE GUERETTE

Diplôme en génie mécanique, Ecole Polytechnique, 1970;
Maîtrise en technologie des véhicules militaires,
RCMS Shrivenham, R.-U., 1979;
Carrière de 20 ans avec les Forces Canadiennes avec le
Génie du matériel terrestre, spécialisé dans la gestion de
flottes de véhicules lourds et les essais de systèmes de mobilité;
Chef durant deux ans, section génie mécanique, Oerlikon Aérospatiale;
Depuis juin 1990, responsable des programmes pour véhicules lourds,
division des systèmes de transport, Environnement Canada.

Biographical Notes

CLAUDE GUERETTE

Graduated in Mechanical Engineering, Ecole Polytechnique, 1970;
Master in military vehicle technology, RCMS Shrivenham, U.K., 1979;
20 year career with the Canadian Forces in Land Material Engineering,
specializing in Heavy Vehicle Fleet Management and Mobility Systems Tests;
For a period of two years, head of Mechanical Engineering Section at Oerlikon
Aerospace;
Since June 1990, in charge of heavy vehicle programs,
Transport System Division, Environment Canada.

'Environmental Policies and Future Regulations on Fuels'

FRANK VENA

Abstract

The following presentation is an overview of the problems associated with atmospheric pollution and summarizes the policies of Environment Canada to address the effect of the transportation sector on ground-level ozone, the Greenhouse Effect and toxic pollutant emissions. These policies include control measures in the context of the federal-provincial management of nitrogen oxides (NO_x) and volatile organic compounds (VOC), as well as the joint Transport Canada and Environment Canada Five-Year Plan to evaluate toxic emissions reduction from transport and other combustible fuels. The guidelines of these programs, including the tightening of emission standards for vehicles, the reduction of sulphur content in diesel fuel, and evaluation programs on the toxicity of fuel additives, under the Canadian Law for the Protection of the Environment, are discussed.

Biographical Notes

ANTHONY C. TAYLOR

Tony Taylor is the Director of Transportation Energy in the Department of Energy, Mines and Resources. . He is responsible for policies and programs to encourage energy conservation in transportation and provide incentives for the development of alternative transportation fuels.

Mr. Taylor has been with the federal government for twelve years. Before that he worked as a consultant for a number of government and corporate clients. He is a Professional Engineer in Ontario, with engineering degrees from Queen's and the University of Toronto. He has a Ph.D. from the Massachusetts Institute of Technology and has taught courses at several universities.

"Canada's Position on Alternative Transportation Fuels"

ANTHONY C. TAYLOR

Abstract

Federal and Provincial governments in Canada have been supportive of alternative fuels for over a decade. Industry too has responded to many of the opportunities: fuel manufacturers and retailers, vehicle conversion companies and vehicle manufacturers have all been involved in alternative fuels activities in Canada. The rationale for this interest and support has been varied, and has included energy security, energy cost savings, industrial and regional, trade opportunities, and environmental benefits.

The main arguments today for Canadian and U.S. interest in alternative fuels appear to be two-fold: fuel diversity and environmental benefits. On the one hand, virtually all of our transportation activity is oil dependent, and vulnerable to oil supply and price difficulties. From the environmental perspective, alternative fuels can produce fewer or less reactive pollutants, and in many cases result in lower emissions of carbon dioxide.

This paper discusses the rationale for an active government role in development of alternative fuels. To establish an alternative fuel in the market place requires many things, including new technology, new patterns of industrial and business activity, new infrastructure and new knowledge and attitudes. It's hard to furnish all of these in an orderly manner. Governments can assist in many ways: they can help improve technology, underwrite risk, bring market actors together to instill confidence in consumers, and provide product standards. Assistance is needed until an "economically sustainable" level of use is reached and the technology is safe and reliable.

The paper looks at the status of alternative fuels in Canada today, especially propane, natural gas, alcohol fuels and electrochemical fuels and indicates some of our successes and difficulties in developing these options.

**CANADA'S POSITION ON
ALTERNATIVE TRANSPORTATION FUELS**

PRESENTATION OF

Mr. Tony C. Taylor

**Energy, Mines and Resources Canada
CANMET**

Sheraton Centre, Montreal

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CANADA'S POSITION ON ALTERNATIVE TRANSPORTATION FUELS

**FEDERAL AND PROVINCIAL GOVERNMENTS IN CANADA HAVE
BEEN SUPPORTIVE OF ALTERNATIVE FUELS FOR OVER A
DECADE.**

**INDUSTRY TOO HAS RESPONDED TO THE OPPORTUNITIES:
PARTICULARLY**

- FUEL SUPPLIERS**
- FUEL RETAILERS**
- VEHICLE MANUFACTURERS**

**THE RATIONALE FOR THIS INTEREST AND SUPPORT HAS
VARIED, AND HAS INCLUDED**

**ENERGY SECURITY
ENERGY COST SAVINGS
INDUSTRIAL AND REGIONAL DEVELOPMENT
TRADE OPPORTUNITIES, AND
ENVIRONMENTAL BENEFITS.**

ENERGY SECURITY

WAS THE DRIVING FORCE IN THE EARLY '80s IN MANY COUNTRIES

EXAMPLES:

- | | |
|---------------|-----------------------|
| SOUTH AFRICA | - SYNFUELS FROM COAL |
| BRAZIL | - ETHANOL FROM SUGAR |
| GERMANY | - METHANOL FROM COAL |
| UNITED STATES | - ETHANOL FROM GRAINS |
| | - SYNFUELS CORP. |

ECONOMIC BENEFITS

SEEM TO BE THE MAIN DRIVING FORCE BEHIND
CURRENT ALTERNATIVE FUELS PROGRAMS IN CANADA

- DOLLAR SAVINGS
- INDUSTRIAL AND TRADE BENEFITS
- REGIONAL DEVELOPMENT
- BALANCE OF PAYMENTS

EXAMPLES IN CANADA: PROPANE AND NGV

OTHER EXAMPLES

JAPAN AND HOLLAND: PROPANE

ITALY AND NEW ZEALAND: NGV

ENVIRONMENTAL BENEFITS

A. URBAN AIR QUALITY

CURRENTLY AN IMPORTANT DRIVING FORCE BEHIND
ALTERNATIVE FUELS IN THE UNITED STATES AND SEVERAL
OTHER COUNTRIES

MANY ALTERNATIVE FUELS CAN REDUCE VEHICLE
EMISSIONS ON CURRENT CARS, AND

CAN REDUCE THE COST OF MEETING EMISSION STANDARDS
FOR NEW VEHICLES

SOME CITIES ARE - REVIEWING, OR
- ENCOURAGING, OR
- MANDATING

EXAMPLES:

LOS ANGELES	- METHANOL
NEW YORK	- NATURAL GAS BUSES
DENVER PHOENIX	- ETHANOL BLENDS
HAMBURG	- METHANOL BLENDS
SEOUL	- PROPANE

CANADIAN CITIES ARE JUST STARTING TO BE AWARE OF THE
VALUE OF ALTERNATIVE FUELS

B. GLOBAL CLIMATE CHANGE

**DISCUSSION JUST BEGINNING OF POSSIBLE ROLE FOR
ALTERNATIVE FUELS HERE**

SOME NEAR TERM OPTIONS PROMISE MODEST IMPACT

FOR EXAMPLE:

**NATURAL GAS AS SUBSTITUTE FOR
GASOLINE**

**OPTIONS WITH SIGNIFICANT IMPACT TEND TO BE EXPENSIVE
TODAY, AND LONGER TERM IN DEVELOPMENT**

**IN SOME CASES, SIGNIFICANT IMPROVEMENT IN
TECHNOLOGY IS NEEDED TO REDUCE COSTS**

EXAMPLES:

**BIOMASS FUELS (ETHANOL AND
METHANOL)**

ELECTRIC VEHICLES

HYDROGEN

**WHAT IS THE CASE FOR AN ACTIVE GOVERNMENT ROLE IN
DEVELOPMENT OF ALTERNATIVE FUELS ?**

**TO ESTABLISH AN ALTERNATIVE FUEL IN THE MARKET
PLACE REQUIRES:**

- NEW TECHNOLOGY
- NEW PATTERNS OF INDUSTRIAL AND
BUSINESS ACTIVITY
- NEW INFRASTRUCTURE
- NEW KNOWLEDGE AND ATTITUDES.

**IT'S HARD TO FURNISH ALL OF THESE IN AN ORDERLY
MANNER. GOVERNMENTS MUST HELP:**

- TO IMPROVE TECHNOLOGY
- TO UNDERWRITE RISK
- TO BRING MARKET ACTORS TOGETHER
- TO INSTILL CONFIDENCE IN CONSUMERS
- TO PROVIDE PRODUCT STANDARDS.

ASSISTANCE IN NEEDED UNTIL

THE TECHNOLOGY IS SAFE AND RELIABLE

**THE OPTION IS BROUGHT INTO THE MAINSTREAM
OF THE VEHICLE AND FUEL INDUSTRIES, AND**

**AN "ECONOMICALLY SUSTAINABLE" LEVEL OF USE
IS REACHED.**

STATUS OF ALTERNATIVE FUELS IN CANADA TODAY:

**SOME POCKETS OF PROGRESS,
BUT OVERALL NOT A RUNAWAY SUCCESS.**

PROPANE

**- THE MARKET HAS BEEN ESTABLISHED
(140,000 VEHICLES, 1% OF LIGHT DUTY
FLEET), BUT VERY LITTLE CONTINUING
GROWTH; SOME TECHNICAL PROBLEMS.**

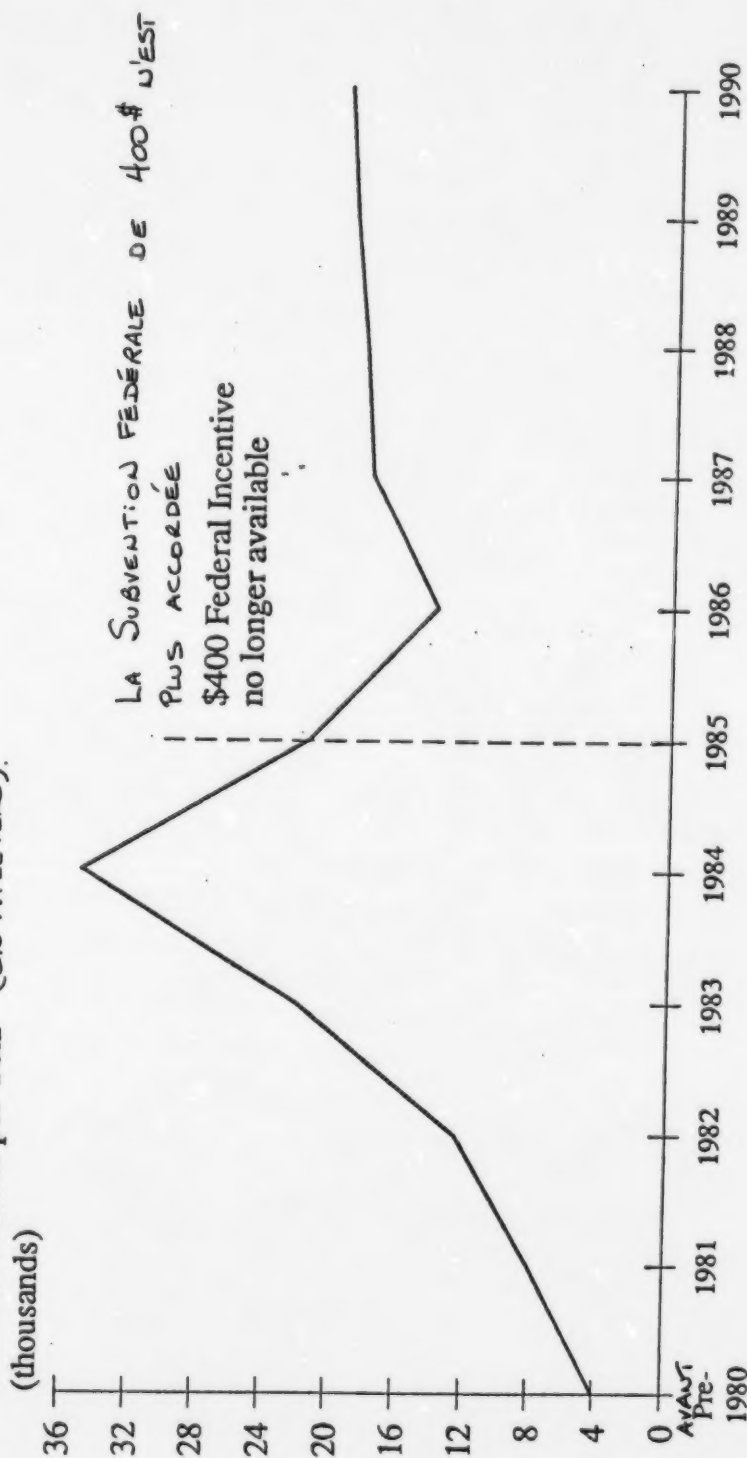
**NATURAL
GAS**

**- A GOOD START, BUT MARKET NOT YET
LARGE ENOUGH TO SUSTAIN; GROWTH MUCH
SLOWER THAN EXPECTED, THOUGH THIS
YEAR'S OIL PRICE INCREASES HELPED.
TECHNOLOGY STILL DEVELOPING.**

TAUX ANNUEL DES CONVERSIONS DES AUTOS AU PROPANE

Auto-Propane Conversions Annual Rate

NUMBRE DE CONVERSIONS PAR ANNÉE
of Conversions per Year (en milliers)



SOURCE: Propane Carburetion Markets in
Canada, Propane Gas Association of
Canada Inc.

ASSOCIATION CANADIENNE DU
GAZ PROPANE

NOTE: Peak fleet size: estimated
at 150,000 vehicles.

TAILLE MAXIMALE
ESTIMATIVE DU
PARC DE VÉHICULES:
150,000 VÉHICULES.

Federal Natural Gas Programs

- (1) The Natural Gas for Vehicles Program (NGVP)
- (2) The Natural Gas Fuelling Station Program (NGFSP)
- (3) The Residential Refuelling Appliance (RRA) Program
- (4) The Commercial Compression Program
- (5) The NGV Market Development/Demonstration Program
- (6) The NGV Technical Program
- (7) The NGV Marketing Program

METHANOL

- VEHICLE TECHNOLOGY NOW PROVEN AND READY FOR MARKET, BUT NO INFRASTRUCTURE TO SUPPORT IT.

ETHANOL

- NOT AN ECONOMICAL FUEL OPTION YET, EXCEPT WHERE PROVINCIAL SUBSIDIES ARE AVAILABLE; NEEDS R&D ON USE OF LOW-COST FEEDSTOCKS.

**ELECTRIC
VEHICLES**

- CONSIDERABLE WORK NEEDED TO IMPROVE THE TECHNOLOGY AND THE ECONOMICS, BUT INTEREST BY VEHICLE MANUFACTURERS INCREASING !

MAJOR ISSUES IN DEVELOPING A NEW ATF POLICY

THERE IS A CASE FOR A MORE EXPLICIT AND MORE AGGRESSIVE POLICY TO DEVELOP:

- **GREATER MARKET USE OF ALTERNATIVE FUELS**
- **MORE COMPLETE PLAN FOR R&D AND TRANSFER OF TECHNOLOGY**

GOVERNMENT ROLE IS CURRENTLY SUPPORTIVE; WE TRY TO FOLLOW THE MARKET.

WE RISK LOSING SOME BENEFITS WITHOUT A DIRECTIVE APPROACH TO PLANNING AND ACTION:

- **KEEPING UP WITH THE U.S. AND OTHER COUNTRIES**
- **EFFICIENT MARKET DEVELOPMENT**
- **ENVIRONMENTAL AND ECONOMIC BENEFITS**
- **POSSIBLE CONTRIBUTION TO ENERGY SECURITY**

U.S. PROPOSALS AND ACTIONS

CLEAN AIR ACT

TIGHTER EMISSIONS STANDARDS FOR ALL VEHICLES

CLEAN FUEL FLEET DEMONSTRATION PROGRAM FOR
SERIOUSLY POLLUTED AREAS

URBAN BUS STANDARDS ROLLED BACK TO 1993 AND
TIGHTENED

TAMPERING DEFINITION MODIFIED TO ALLOW VEHICLE
CONVERSIONS

NATIONAL ENERGY STRATEGY

ALTERNATIVE FUELS TO REPLACE 2 MILLION BARRELS OF
OIL PER DAY BY 2010

CENTRALLY-FUELED FLEETS WILL BE REQUIRED TO
PURCHASE ALTERNATIVE FUEL VEHICLES

INCREASE FEDERAL PURCHASES OF ALTERNATIVE FUEL
VEHICLES

THE ALTERNATIVE FUEL CREDIT UNDER THE "CAFE"
PROGRAM WILL BE INCREASED

NEW RESEARCH PROGRAM WITH AUTOMOBILE
INDUSTRY TO ACCELERATE DEVELOPMENT OF
ELECTRIC VEHICLES

CANADA'S STRATEGY

CONTINUE TO SUPPORT ALTERNATIVE FUELS IN THE MARKET

INCREASE RESEARCH AND DEVELOPMENT ACTIVITY ON LONGER TERM OPTIONS

GREEN PLAN

PROGRAMS PROPOSED IN SEVERAL AREAS

- **R&D AND DEMONSTRATIONS**
- **CAREFUL ASSESSMENTS OF ATF POTENTIAL**
- **FEDERAL USE OF ALTERNATIVE FUELS**
- **NEW MARKET PROGRAMS FOR NGV**
- **INCREASED AVAILABILITY OF ATF VEHICLES**

DETAILS TO BE ANNOUNCED THIS SPRING.

VINCENZA ALLENGER

Notes biographiques

Vincenza Allenger est titulaire d'un diplôme en génie chimique de l'université McGill et d'un doctorat de l'université d'Ottawa. Elle est ingénieur professionnel et travaille pour CANMET depuis 1982. Depuis lors, elle a exploré de nouveaux domaines et établi un champ d'expertise en technologie de conversion du gaz naturel, qui manquait aux LRÉ jusqu'en 1982. Elle dirige la section de la conversion des hydrocarbures des LRÉ, où se font des conversions de gaz naturel. Elle établit les priorités et présente les projets de recherche pour la cellule Technologie. À titre de chef de projet pour le Consortium de recherches sur la conversion du gaz naturel de CANMET, elle se charge d'attirer la participation des industries et d'assurer un haut niveau d'activité scientifique.

Mme Allenger détient, au Canada et aux États-Unis, des brevets concernant la technologie "Méthane à isobutylène" de CANMET. L'isobutylène est un dérivé de la pétrochimie d'une importance stratégique qui sera très demandé pour la synthèse du MTBE (2-méthoxy-2-méthylpropane).

Biographical notes

Vincenza Allenger is a chemical engineering graduate from McGill University and holds a doctorate degree from University of Ottawa. She is a professional engineer and has been with CANMET since 1982. Since that time she has broken new ground and established an expertise in the Natural Gas Conversion Technology which was non-existent at ERL prior to 1982. She heads ERL's CI Conversion section where natural gas conversion activities are carried out. She sets priorities and defends research projects for the Natural Gas Conversion she is responsible for attracting industrial participation and for ensuring a high level of scientific activity.

Dr. Allenger has patents in Canada and the U.S. for CANMET's Methane to Isobutylene (MTI) technology. Isobutylene is a strategic petrochemical with a strong future demand in MTBE synthesis. (2-méthoxy-2-méthylpropane)

Liquid Fuels Made from Natural Gas

**Vincenza Allenger
Head, Hydrocarbon Conversion Section
Energy Research Laboratories, CANMET
Energy, Mines and Resources Canada
Ottawa, Ontario
K1A 0G1**

**Energy and Environment Conference
Sheraton Centre
Montreal, Quebec
March 20 and 21, 1991**



Introduction

Mr Chairman, Ladies and Gentlemen, I am delighted to be able to talk to you today about the development of natural gas. My presentation is twofold: first, I want to impress upon you the development potential of a very new market for natural gas and, second, I would like to talk about the research programs currently under way at CANMET.

World Reserves

The abundance and the balanced distribution of gas reserves on every continent are the most powerful incentive for increasing natural gas production and research.

Great Britain, Norway, the United States, Australia and other countries have devoted a considerable amount of energy to research on gas technologies, including the production, transportation, distribution and chemical conversion of natural gas. In all of these countries, Canada included, governments, gas and oil companies and intergovernmental agencies are among the key players in devising technological strategy.

What is new in Canada and other countries, with regard to the technologies involved in the exploration, extraction and supply of natural gas from conventional and unconventional sources, is research on how to obtain natural gas from so-called unconventional sources.

Natural gas is transported by pipeline in the form of compressed gas at 80 bars or in natural gas tankers in the form of liquified gas cooled to -162°C , at 1/600th of the gas volume. Transportation costs can be expected to rise more and more as unconventional supply sources are developed farther and farther away from consumer areas. It would thus be preferable for

producing countries, Canada included, to convert natural gas directly into liquid fuels at production sites.

Natural Gas and the Environment

"Gas processors are perhaps more accustomed to dealing with environmental matters than any other group in the energy sector. Through their excellent safety record over the past few decades, they have demonstrated that an environmentally sensitive product can be delivered to market in a responsible fashion."²

Natural gas contains no sulphur or nitrogen oxide. Natural gas therefore burns much more cleanly than other fossil fuels. Comparisons among fuels for thermal power plants, industry and home use illustrate the many advantages of natural gas³. Its combustion properties make it a preferred choice among fossil fuels.

Recent advances in gas technologies have been made mainly in techniques for using natural gas. Work is being done in various sectors, ie in industry, homes and transportation, across Canada and especially in Quebec³.

The potential for the transportation sector is enormous. Research currently under way is concerned especially with public transit and school vehicles and commercial road transportation (trucks and vans). There are still major challenges facing natural gas vehicles, however.

A relatively unknown market to date in Canada is the development of natural gas with a view to substituting it for oil products as a source of petrochemicals, for example, the cracking of naphtha into isobutylene. Use of this less-polluting source would be an energy and environmental plus.

The Technological Challenge

Most natural gas chemical transformation processes involve conversion into a synthesis gas ($\text{CO} + \text{H}_2$), which results in considerable energy loss. Any method involving the direct conversion of methane would therefore be much more appealing than existing methods. Such technologies are unfortunately unavailable at present and come up against the problem of the considerable chemical inertia of methane and the relatively unfavourable thermodynamics of its conversion.

The problem of the chemical conversion of methane is twofold and involves:

- finding a way of activating the C-H bond in methane. This can be done by the oxidative addition of methane on a reduced metal, by electrophilic substitution or by thermal or catalytic free radicals;
- using a hydrogen acceptor cosubstrate to make overall conversion thermodynamically appropriate. The cosubstrate may be molecular oxygen, halogen or unsaturated hydrocarbon, among others.

Catalytic and Non-Catalytic Methane Coupling

Methane coupling by thermal dehydrogenation makes it possible to convert methane into ethylene and acetylene. This reaction is highly endothermic and takes place at very high temperatures. Contact times are also very short and are followed by very rapid cooling-off, in particular using an electric arc or plasma. A techno-economic study by SNC Inc. showed that the process was viable.

The reaction between methane and chlorine at high temperatures also leads to the formation of a mixture containing mainly ethylene, acetylene, hydrochloric acid and hydrogen.

The oxidation of methane into ethane-ethylene with molecular oxygen can occur in cofeed mode (feeding a methane-oxygen mixture into the reactor) or in redox mode (oxidation of methane into hydrocarbons by the catalyst, followed by reoxidation of the catalyst by the air; sequential feeding of CH_4 , air and inert gas over the catalyst). The oxidative coupling of methane into ethylene by means of heterogeneous catalysis is certainly one of the most promising reactions for the future. Much progress remains to be made, however, to render this reaction industrially viable:

1. Catalyst activity is weak, requiring reactor volumes that are much too high to obtain an acceptable methane conversion rate.
2. The selectivity of C_2+ coupling products is insufficient, and too much CO_2 is produced. The ethylene-ethane ratio must be increased.
3. The reaction temperature is too high and requires the use of reactors with inert ceramic walls. Increased catalyst activity would make it possible to operate at lower temperatures and thus increase selectivity.

Ethylene and acetylene can be converted into aromatics by using zeolites that are often doped with gallium. It is not very efficient, however.

Partial Oxidation of Methane

The direct oxidation of methane into methanol and/or formol is of considerable industrial interest. Even though it is thermodynamically appropriate, the partial oxidation of methane into methanol or formol and water is very difficult owing to the oxidation potential of the latter, which is much greater in CO and CO₂ than that of methane. On the whole, the results obtained are still not promising enough to compete with the current process for making methanol from synthesis gas⁴.

Other Conversions

Conversions by superacids

In a superacid medium, such as TaF₅ - HF, methane can be protonated into the methane cation CH₅⁺ and, through various chemical reactions that have been postulated, can be added to ethylene to produce propane. The CANMET's MTI procedure⁴, based on catalysis through superacids, is an isobutylene synthesis process.

Conversion of methane, ethane and propane by oxidation

Diversification in the transportation industry is opening the door to alcohols as the fuels of the future or as additives. This list includes methanol, ethanol and isopropanol. Use of the additive MTBE, synthesized from methanol and isobutylene, by a few refineries after lead is removed has increased the importance of these chemical and oil products. The oxidative conversion of these alkanes is therefore of greater commercial interest. The conversion of butane into maleic anhydride is another example of the industrial possibilities⁵.

CANMET Research Program

Natural gas conversion studies are ongoing at CANMET's laboratories in Ottawa and Varennes. Research activities conducted at CANMET are concentrated in four different areas.

1. Research conducted within the CANMET's laboratories for the Research Consortium on Natural Gas Conversion.
2. Studies on other processes, such as the MTI process.
3. Studies directed by CANMET but which are done outside the organization, under contract by private industry.
4. Contacts with other researchers and organizations and participation in research programs abroad.

As such, research projects on direct conversion deal with such themes as:

- oxidative catalytic coupling of methane and ethane;
- partial oxidation of methane, ethane and propane;
- methane reactions in a superacid medium.

Involvement of Canadian Industry

CANMET has formed an industrial consortium with a view to continuing research on the various options for developing natural gas. Representatives of the first four corporations to join the consortium, Gulf Canada Resources Limited, Shell Canada Limited, Canadian Occidental Petroleum and Gaz Métropolitain, met in Ottawa recently to launch the second year of this initiative. In order to take part, these corporations had to sign an agreement protocol. The protocol details the legal aspects of the consortium's

operation and specifies how the intellectual property resulting from research will be used.

The general objective of the research program is to examine options for the chemical development of natural gas. These options are being studied at the experimental level in the ERLs, and the development of promising technology is being speeded up by technological transfer. Each member of the consortium provides technical assistance and helps outline research projects that are conducted in the ERLs.

The \$480,000 research program is financed equally by CANMET and the consortium members (eight in all). Each corporation provides \$30,000 per year. CANMET is looking for other participants to expand its research program.

Conclusion

The transition to an energy system not based on fossil fuels is an environmental certainty. However, the development and support of technologies based on natural gas would allow us to make this transition more carefully as we acquire more knowledge through our research on the overall carbon cycle.

In his speech to the 30th annual meeting of the Canadian Gas Processors Association last fall, the Honourable Jake Epp challenged "... the gas processing industry to share its environmental awareness and expertise with other Canadians."²

I hope that this overview of natural gas conversion technologies has illustrated the enormous potential that remains to be explored and the key role to be played by natural gas in the responsible and efficient use of our resources.

In conclusion, I would also like to draw your attention to a conference on natural gas entitled "Natural Gas Conversion: Advances and Future Challenges", sponsored by CANMET, to be held in Calgary, Alberta, on June 13 and 14, 1991.

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